AD-A151 728 MICROPROCESSOR AIRBORNE DATA ACQUISITION & REPLAY (MADAR) SYSTEM(U) AERONAUTICAL RESEARCH LABS MELBOURNE (AUSTRALIA) C W SUTTON ET AL. MAR 84 ARL/AERO-R-159 1/1

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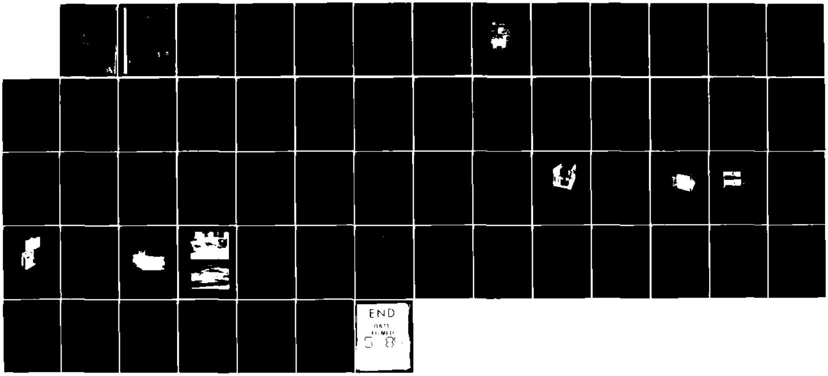

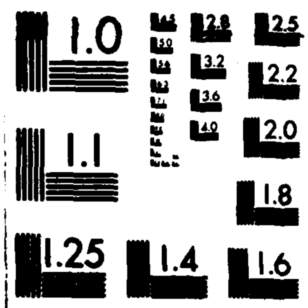
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AERODYNAMICS REPORT 159

MICROPROCESSOR AIRBORNE DATA ACQUISITION & REPLAY (MADAR) SYSTEM

by

C. W. SUTTON and J. F. HARVEY

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AERODYNAMICS REPORT 159

MICROPROCESSOR AIRBORNE DATA ACQUISITION & REPLAY (MADAR) SYSTEM

by

C. W. SUTTON and J. F. HARVEY

SUMMARY

This paper describes a self-contained data acquisition system capable of real time data processing and display during recording.

Replay options include hard copy of data to an X–Y recorder or terminal printer and transfer of data to a computer.

Additional keywords: microprocessors, analog to digital converters, user manuals, digital recording systems, cassettes, data displays

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CONTENTS

1. INTRODUCTION

The need for a smart versatile data acquisition system arose from discussions with Aircraft Maintenance And Flight Trials Unit (*AMAFTU*) at HMAS *Albatross* while participating jointly in Sea King mathematical model validation flight trials during August 1979.

Many *AMAFTU* tasks involve measurement of flight performance. One such example is in-flight calibration of cockpit instruments. For this application an idea evolved whereby transducer signals (from a boom) could be recorded within the aircraft and selected data processed in-flight to provide corrected displays of measured parameters. For quick-look verification, the pilot would compare the cockpit instrument readings under various flight conditions with the readings produced on the installed displays. The in-flight gathered raw data would be available for later analysis.

The boom was envisaged as a general purpose quick-fit type, calibrated for use with a range of different aircraft.

The concept was modified such that the microprocessor module was not dedicated to boom usage but a versatile instrument for other applications. The microprocessor module (Fig. 1) became known as the Microprocessor Airborne Data Acquisition and Replay (*MADAR*) system.

2. DESIGN CONCEPT

2.1 General

The design is based on a 16-bit microprocessor supported by in-house designed and proven printed circuit cards (Section 8.2) with a digital cassette as the recording media. The specification for *MADAR* is detailed in Appendix 1.

Microprocessor control is programmable by keypad, external printer/keyboard, conventional computer terminal (e.g. Video Display Unit or Teleprinter Model 43) or computer.[1]

Whilst recording, the microprocessor is able to process selected data and update various liquid crystal displays several times a second. A six-digit front panel display gives visual readout of keypad entries and selected parameters such as time or the sign and magnitude of an analogue signal at the input of any channel. A dedicated four-digit display, in the hand-held remote control unit, automatically shows 'Run No.' and 'Tape Time Remaining'. Provision exists for five (with possible extension to eight) external displays for user allocation.

On replay, a file search of recorded Run numbers is provided and quick-look options allow selected data blocks within a nominated 'Run No.' file to be sorted into channels, tabulated and printed in Hexadecimal code or signed decimal values of voltage. Alternatively, data may be graphed on an X-Y recorder. Raw data may also be replayed from tape and serially transmitted to a computer at either 300 or 1200 Baud.

Provision exists for specific application programs to be developed and recorded as object files on cassette tape. When replayed by *MADAR*, the application program automatically loads into assigned battery-powered memory which is periodically accessed by the resident control program. Alternatively, the application program object file may be stored in Read Only Memory (*ROM*) which is automatically accessed by the resident program. This minimises the need to modify the *MADAR* resident control program when used in various trial applications.

It is envisaged that the application programs perform simple real-time calculations on selected data, for the purpose of presenting a display of corrected data scaled in appropriate units.

———[1] Harvey, J. F., Sutton, C. W., and Kerton, I. M. Operating Instructions Manual for Microprocessor Airborne Data Acquisition and Replay (*MADAR*) Module, Aero Tech. Memo 347, February 1983.

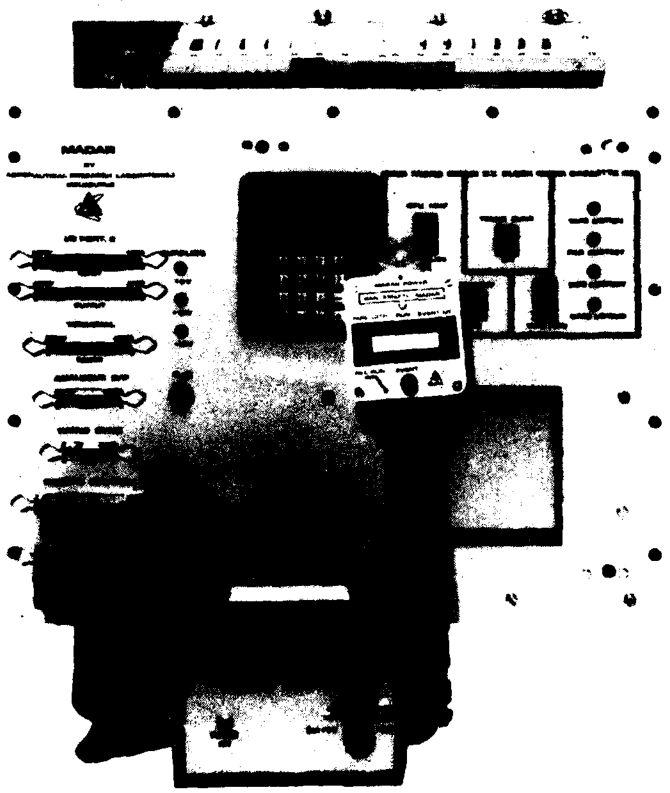


FIG. 1 MADAR MODULE WITH HAND-HELD CONTROL UNIT AND MONITOR

2.2 Data Handling

Analogue signals either pass through low-pass filters or directly connect to a 16-channel analogue multiplexer with sample and hold facilities.

Periodic interruptions to the microprocessor from a crystal controlled Real Time Clock (*RTC*) initiate sequential addressing of selected channels at a preselected sample rate. An analogue to digital (*A/D*) conversion is completed 35 microseconds after the multiplexer is addressed and the generated 12-bit binary data word, plus 4-bit high order address word, stored as a 16-bit word in semiconductor Random Access Memory (*RAM*) which is programmed to function as a circulating buffer.

As the buffer fills, a software trip point is reached which causes the microprocessor to start the cassette recorder and transfer stored words from the buffer to the recorder. On transfer of a preassigned number of words the microprocessor automatically closes the data block with an Inter-Record-Gap (*IRG*) or terminates the recording with a post-data gap and a controlled tape drive stop.

Transfer of data from the buffer occurs only whilst the recorder is writing and requires that *16-bit data words* be parallel loaded to the recorder interface every 2 milliseconds. A maximum of 125 microseconds is available to load the recorder interface once the reload flag occurs. This is the time between the occurrence of the reload flag, when the last bit of the present word has been serialized onto the tape, and a recorder generated clock pulse which serializes the first bit of the next word on to tape.

3. BUFFER DESCRIPTION

3.1 General

The buffer (Fig. 2) is a continuous block of *RAM* that extends from the low address of FIRST to the high address of FLEXP (max). The address contained in LIMIT is the nominal upper limit of the buffer and the value in MARGIN ensures that sufficient buffer capacity remains for the recorder to start, reach operational tape speed and insert the post-data gap without risk of buffer overflow.

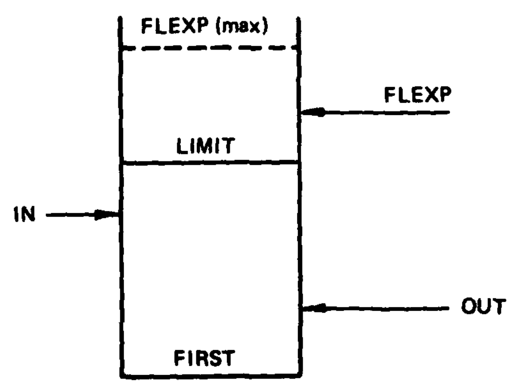


FIG. 2 BUFFER WITH LABEL VALUES

The pointers IN, OUT and FLEXP are assigned base page *RAM* locations and FIRST, LIMIT and MARGIN are fixed values in *ROM*.

For initial use:

$$IN = OUT = FIRST$$

and

$$FLEXP = LIMIT$$

3.2 Pointers

Three pointers are associated with the buffer. The IN pointer contains the buffer storage address for the next data word.

The *OUT* pointer contains the buffer address from which the next data word is to be obtained for transfer to the recorder interface.

The FLEXP pointer contains the buffer address at which the IN pointer was reset.

When:

IN = OUT   Buffer is empty (or has filled).

If:

OUT + 1 = IN   Buffer is full.

Wrap around of the IN pointer, to produce a circulating buffer, occurs when:

IN > LIMIT

To minimize instruction time during buffer management, the IN wrap around is checked only after all the data of a sampled operation are stored in the buffer at which time the IN pointer has stepped N addresses.

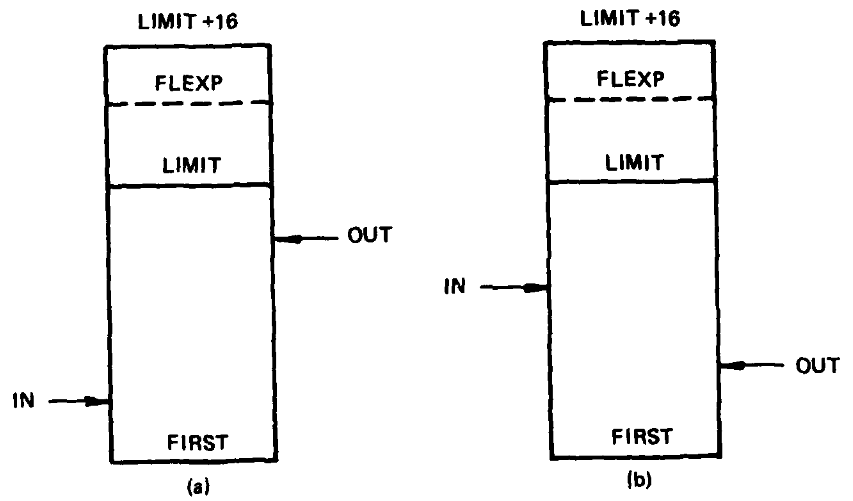


FIG. 3 TWO COMBINATIONS OF IN & OUT POINTERS

If, following the store operation:

IN > or = LIMIT

then:

FLEXP is made equal to IN

and

IN is made equal to FIRST

Otherwise:

IN < LIMIT

which leaves FLEXP and IN pointers unchanged.

The step size of N is variable and equals the number of selected channels bulk deposited into the buffer during a sample sequence. The maximum value for N is 16, thus the upper address allocation for buffer memory is:

$$\text{FLEXP (max)} = \text{LIMIT}+16$$

As data words are singularly transferred from the buffer to load the recorder interface the OUT pointer increments and wrap around of the OUT pointer occurs when:

$$\text{OUT} = \text{FLEXP}$$

Then:

OUT is reset to equal FIRST

3.3 Margin

With the RECORD S/W 'ON', and no tape motion, the OUT pointer is stationary and each N step of the IN pointer reduces the remaining capacity of the buffer. Eventually buffer overflow will occur unless the recorder starts and allows the OUT pointer to move.

Figure 3 shows two combinations of the IN and OUT pointers for which the nominal remaining capacity of the buffer is determined.

Ignoring the additional storage locations between LIMIT and FLEXP then the nominal remaining capacity (Cr) becomes:

For Fig. 3(*a*) where IN < OUT

$$Cr = \text{OUT}-\text{IN}$$

and for Fig. 3(*b*) where IN > OUT

$$Cr = \text{LIMIT}-\text{IN}+\text{OUT}-\text{FIRST}$$

rearranged:

$$Cr = \text{LIMIT}-\text{FIRST}+\text{OUT}-\text{IN}.$$

Let the nominal capacity (C) of the buffer be:

$$C = (\text{LIMIT}-\text{FIRST}).$$

Then:

$$Cr = C+\text{OUT}-\text{IN}.$$

When the nominal remaining capacity (Cr) reduces to less than a preassigned value (MARGIN) then the software trip point is reached which starts the recorder.

From Section 3.5 the minimum value for MARGIN is 115 (memory locations). The actual value assigned is:

$$\text{MARGIN} = 240.$$

Hence the recorder starts when:

$$Cr < 240.$$

3.4 Storage Rate

The rate at which data words are stored in the buffer is dependent upon the number of selected channels and associated sample rates and is:

$$(N1 * S1 + N2 * S2) \text{ words/sec.}$$

Where:

$N1$ is the number of channels selected at $S1$ samples/sec

$N2$ is the number of channels selected at $S2$ samples/sec.

The maximum storage rate of 320 words/sec occurs when all 16 channels are selected and are sampled at 20 times/sec.

With the RECORD switch held 'ON', the time ($t1$) to reduce the nominal remaining capacity (Cr) to that of MARGIN and thereby start the recorder is:

$$t1 = (C - \text{MARGIN})/(N1 * S1 + N2 * S2) \text{ Seconds.}$$

3.5 Peak Capacity

When the recorder starts, a nominal 0·14 seconds is required for tape motion to reach operation speed and a further 0·2 seconds to produce the pre-data gap. An additional 0·016 seconds is required to write 8 status words. Thus 0·36 seconds elapse before data are removed from the buffer, during which time approximately 0·36 ($N1 * S1 + N2 * S2$) words are stored. This represents 115 words at the maximum storage rate and must not exceed the assigned value for MARGIN if buffer overflow is to be avoided.

The peak content (Cp) of the buffer becomes:

$$Cp = C - \text{MARGIN} + 0{\cdot}36\,(N1 * S1 + N2 * S2).$$

Since from Section 3.3

$$C = (\text{LIMIT} - \text{FIRST}).$$

Then:

$$Cp = (\text{LIMIT} - \text{FIRST}) - \text{MARGIN} + 0{\cdot}36\,(N1 * S1 + N2 * S2).$$

The assigned values for LIMIT and FIRST allows sufficient storage for a minimum of two data blocks to be written without stopping the recorder.

3.6 Removal Rate

While the recorder is writing the content of the buffer reduces to a trough, immediately a data block is completed, and increases to a peak just after the start of the following data block. The peak and trough values converge to zero provided that the effective removal rate of data from the buffer is greater than the storage rate.

With the tape moving at operational speed, the effective removal rate of data words from the buffer is set by the 500 data words/second writing limit of the recorder and the time needed for gap generation.

The time $t2$ required to write W data words on tape is:

$$t2 = W/500 \text{ Seconds.}$$

Assuming 0·2 second inter-record gaps and allowing for 8 words of status data originating from scratch pad *RAM*.

The time $t3$ between consecutive peaks is:

$$t3 = 0{\cdot}2 + W/500 + 8/500.$$

With $W = 256$ then $t3 = 0{\cdot}73$ seconds.

The effective writing rate during $t3$ is 364 words/second. However, only 256 words are removed from the buffer during this period giving a removal rate from the buffer of 350 words/second or about 10% greater than the maximum storage rate of 320 words/second (Section 3.4).

3.7 Recorder Control

As described in Section 3.3 the recorder starts when the buffer fills beyond the value set by MARGIN.

At the completion of every inter-record gap, the peak value (Pn) is checked to determine if sufficient data remain in the buffer to allow another data block to be written on tape without the need for fills.

If:

$$Pn > W$$

transfer of data from buffer to tape is recommenced.

If:

$$Pn < W$$

then the state of the RECORD switch is checked (Fig. 4).

If the RECORD switch is 'ON' then the gap is considered a post-data gap and the recorder is stopped.

If the RECORD switch is 'OFF' then the data remaining in the buffer are transferred to tape until emptied. Fills are inserted to complete the data block.

Hence only the last data block of a data gathering run contains fills as the buffer is forced to empty. (During replay, these fills appear as data in Channel 1 with a Hexidecimal value of 0000 but may be masked out after replay by logic reference to the sample count of another channel).

4. RESIDENT PROGRAM CONTROL

4.1 General

At power-up (and whenever *MADAR* is otherwise INITIALIZED) the resident program executes a single pass, to overwrite specific *RAM* addresses with predetermined values. A loop is then entered which periodically senses for the desired control mode. The loop branches automatically to service the mode set by the operator and on completion of the service returns again to the loop.

The PROGRAM mode (Section 4.2) services entries from the keypad or, if connected, a keyboard or computer. No critical time constraints are involved.

However, service time is critical in RECORD and REPLAY modes as data are written and read, with tape motion. Also, the RECORD mode involves further time critical operations to sample selected channels at predetermined rates and to refresh displays.

While in the RECORD mode the resident loop program also senses for, and if necessary branches to, an applications program previously loaded into *RAM* by the user (provided pins 13 and 14 are linked on the FRONT PANEL TEST connector). An application program in *ROM* may also be included in the loop provided that the first instruction (at address 0800) is not 0FFFF.

The record format for data and application program files is shown in Appendix 2.

4.2 PROGRAM Mode

In the PROGRAM mode, the loop checks the priority of the communicating device. With no connection to I/O PORT 2 or TERMINAL then keypad operation is assumed.

Whenever one of the 16 keypads is pressed, an interrupt service routine addresses the keypad and stores the unique 4-bit code. Further keypad entries are accepted during subsequent passes of the loop through the PROGRAM mode and each entry is checked for sequence in a valid string. Valid entries for keypad use are detailed in TABLES 1 and 2. An invalid entry forces 99999 on the internal display (TABLE 3) and requires a retry.

A keyboard/printer connected to I/O PORT 2 automatically has preference over the keypad and communication is in parallel ASCII.

A computer connected to TERMINAL automatically causes the resident program to provide serial ASCII communication and skip service of the keypad and I/O PORT 2.

Valid command strings for I/O PORT 2 and TERMINAL operation are detailed in Section 5.2.

Inserting 'Y' in response to the prompt, instead of channel numbers, displays all the data in Hexidecimal code instead of signed decimal. As only 4 characters, excluding the space, are required for each value then the display is automatically set 4 columns wide for the printer or 16 columns wide for other terminals.

Example:

```
Y
0058  FFFF  11FF  EE80  }  BLOCK STATUS
EF8F  90CC  031B  0000  }
7456  742D  7402  084B     DATA
18A0  27A0  3810  44D2
(until block ends)
```

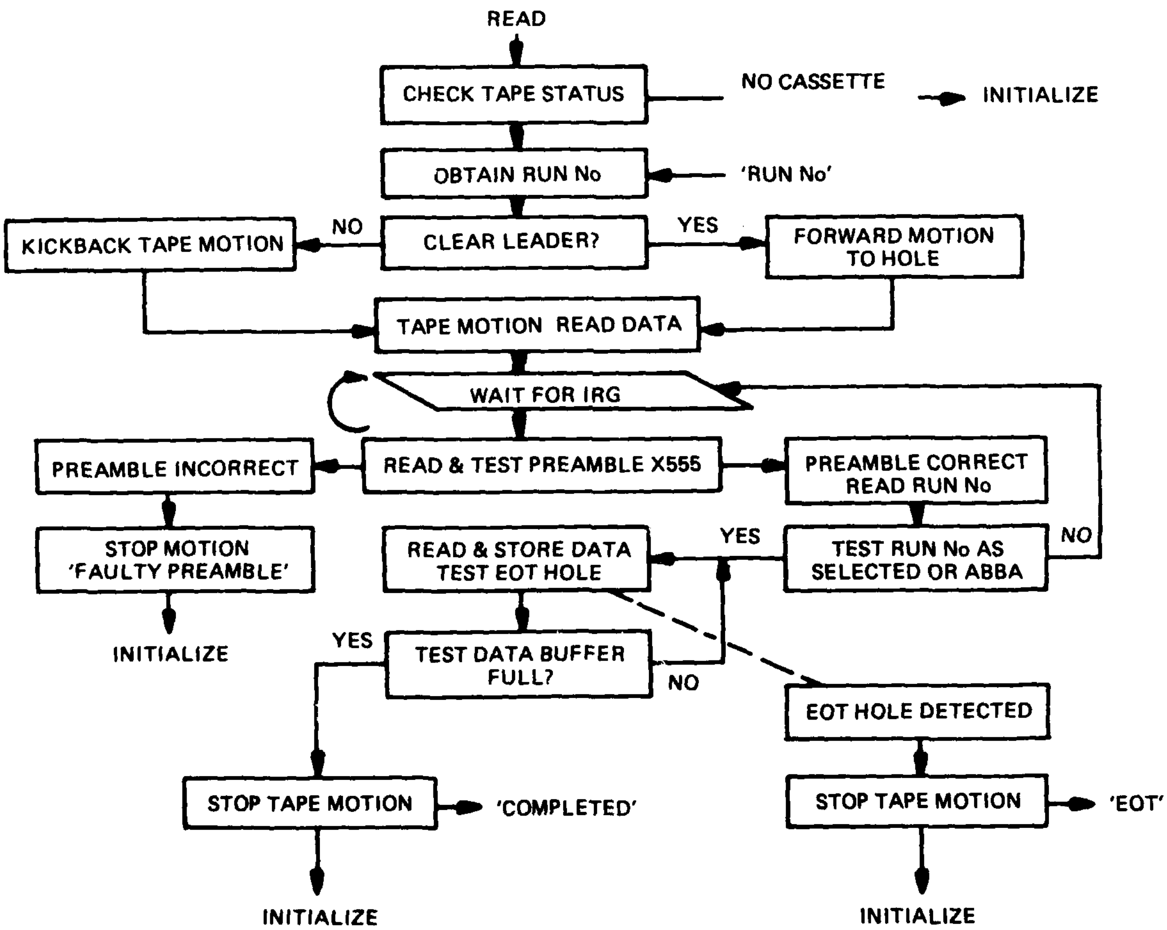


FIG. 14 'R' COMMAND ROUTINE

Where:

TAPE SIDE A

If the cassette is turned through 180 degrees the response would be TAPE SIDE B. Having identified the side being accessed the next response is:

TYPE RUN NO:

The user may respond by entering ABBA or the desired RUN No. within the range 00 to 99. With ABBA, the first detected data block is accessed while a unique RUN No. initiates a file search of the tape.

In either case, completion of a successful operation stops tape motion and COMPLETION is printed. One block of data will then have been read and transferred to the buffer.

When a preamble is incorrectly read, tape motion stops and FAULTY PREAMBLE is printed. The user may either rewind the tape and try again or wind the tape forward slightly to skip the problem block.

Whenever a clear leader or End Of Tape (*EOT*) hole is sensed, tape motion stops and HALT *EOT* is printed.

If there is no cassette in the tape transport when an R command is attempted, tape drive is inhibited and NO CASSETTE is printed.

The replay routine associated with the R command is outlined in Fig. 14.

5.2.8 D—Display Data Buffer

The 'D' command displays the *RAM* content of the data buffer which has the preassigned address range 0100 to 0207. Data, read from cassette tape are stored, a block at a time, in this buffer.

The prompts start with:

TYPE 1 TO 16
FOR ALL TYPE Y

Inserting channel numbers, separated by commas, gives the output data scaled in decimal voltage with each column assigned a channel number.

Example:

1,2,8	(Channel Nos)
0058 51367	(RUN No. and TIME)
−0·186 −0·392 +2·586	(Data)
−3·538 −0·359 +2·767	(Data)
....	

(until block ends)

Each signed value requires 6 characters (excluding the space) and a maximum of 10 channels may be inserted provided that the remote terminal is either a Teletypewriter or *VDU*. However, a maximum of 3 channels applies if the keyboard-printer is used, because of the restricted line width.

5.2.5 L—Lists Current Status

When 'L' is typed the status of all 16 channels is automatically listed as:

Example:

Current Status

CHAN	IN	GAIN	SAMP
01	YES	HIGH	HIGH
02	NO		
03	YES	LOW	HIGH
(STATUS LISTED FOR ALL 16 CHANNELS)			
15	YES	HIGH	LOW
16	NO		

5.2.6 C—Changes Status

The 'C' command enables the channel selection status to be changed. A prompt allows the channel to be identified by entering the channel number followed by a comma (,).

ENTER CHAN NO, (1–16)

Following a correct entry, the user is prompted by:

L/H SETS SAMPLE RATE
0 CANCELS CHAN

A low (*L*) or high (*H*) sample rate option is offered or alternatively a zero (0) causes the channel to be skipped during data gathering operations.
If a sample rate is selected a further prompt is provided:

L or *H* SETS GAIN

Either a low (*L*) or high (*H*) gain may be assigned to the channel.
Incorrect entries produces the prompt:

— TRY AGAIN
ENTER CHAN NO, (1–16)

The program loops to the start of the C command on completion of a valid change and the ESC key returns the program to *MADAR* CONTROL [H].

5.2.7 R—Replay from Tape into Data Buffer

The 'R' command enables data to be read from cassette tape into buffer memory (Section 5.2.9).

Example:

R
TAPE SIDE A
TYPE RUN NO:
0058
COMPLETED

5.2.2 A—Store Data

The 'A' command alters only *RAM* locations. A single location or a consecutive block of memory may be altered. This command enables user programs in machine code to be entered into memory.

Example:

A
0100, 1900, 5C00, 99FE *CR*

The terminal displays:

0100, 1900
0101, 5C00
0102, 99FE

5.2.3 G—Begin Execution

The 'G' command executes programs residing in memory. The entry address of the program is entered and following the carriage return the micropressor operates under control of the user program. *MADAR* only regains control if:

(a) the INITIALIZE switch is pressed

or

(b) the user program under execution returns control to the Initialize routine.

Example:

G
0400 *CR*

The program begins execution at *RAM* location 0400.

5.2.4 P—Print Memory

The 'P' command is similar to the Type Memory 'T' command. Instead of each memory address being printed alongside its stored value, the start and finish address of the memory block are printed followed by all the resident values of that block.

Example:

P
0100 : 0107 *CR*

1234 2345 3456 4567 5678 6789 789A ABCD

A *VDU* usually displays 80 characters/line and *MADAR* responds by printing 16 words to a line. Each word consists of 4 characters separated by a space.

Typically the keyboard-printer is limited to 20 characters/line and only 4 words/line are used.

Example:

P
0100 : 0107 *CR*

1234 2345 3456 4567
5678 6789 789A ABCD

The keyboard–printer is a simple portable terminal, consisting of an ASCII keyboard and a twenty-character width printer. This terminal connects to *MADAR* through two front panel connectors. Data transmit and receive are via parallel lines to the microprocessor bus, through an I/O latch circuit card (I/O PORT 2).

Two options exist for priority three and depend upon the position of the RUN/PROGRAM switch.

In the *RUN* position, control is via the Remote Control Handle. If this handle is not connected to *MADAR* then control automatically reverts to the front panel Keypad.

In the PROGRAM position, control is via the Keypad unless a remote terminal or the keyboard–printer is connected.

5.2 User Prompts

User prompt occurs automatically after INITIALIZATION on either the Remote terminal or the keyboard–printer. The prompt is:

MADAR CONTROL [H]

The prompt informs the user that the microprocessor is waiting for a user command. The [H] is a reminder of the HELP message that is displayed by pressing the H key on the keyboard. *MADAR* responds by generating the following message:

```
T  XX : YY
   TYPE MEMORY FROM
   XX TO YY, 1/LINE
A  XX, DD, DD, . .
   STORE DATA
   BEGINNING AT XX
G  XX
   BEGIN EXECUTION
   AT XX
P  XX : YY
   PRINT MEMORY FROM
   XX TO YY, Z/LINE
D  PRINT DATA BUFFER
R  REPLAY FROM TAPE
   INTO DATA BUFFER
L  LISTS CURRENT STATUS
C  CHANGES STATUS
Z  PLOTS DATA
   1 CHANNEL V TIME
Q  CONTINUOUS REPLY
X  PROGRAM FROM TAPE
MADAR CONTROL [H]
```

5.2.1 T—Type Memory

The 'T' command displays the contents of the microprocessor memory, either *RAM* or *EPROM*.

A single location of memory may be displayed, or a consecutive block of memory by inserting the start address of the block then a delimiter (:) followed by the end address of the block and a carriage return (*CR*). Addresses and memory content are in Hexidecimal code.

Example:
T
0100 : 0103 *CR*

0100, 1234
0101, 2345
0102, 99FD
0103, 1900

5. REPLAY

5.1 Control Priority

On 'INITIALIZATION' of the microcompressor, either automatically at power-on or by activating the INITIALIZE switch, all external peripheral connections are sensed to determine the control device (Fig. 13). The order of priority for control of *MADAR* is:

1. Remote terminal
2. Keyboard—printer
3. Keypad and Display (Remote Control Handle if in RUN mode).

The Remote terminal may be either a Teletypewriter or a Visual Display Unit (*VDU*). Interface to the terminal is via serial RS232C lines. The transmit and receive rate is selectable at either 300 or 1200 Baud via an internal two position switch.

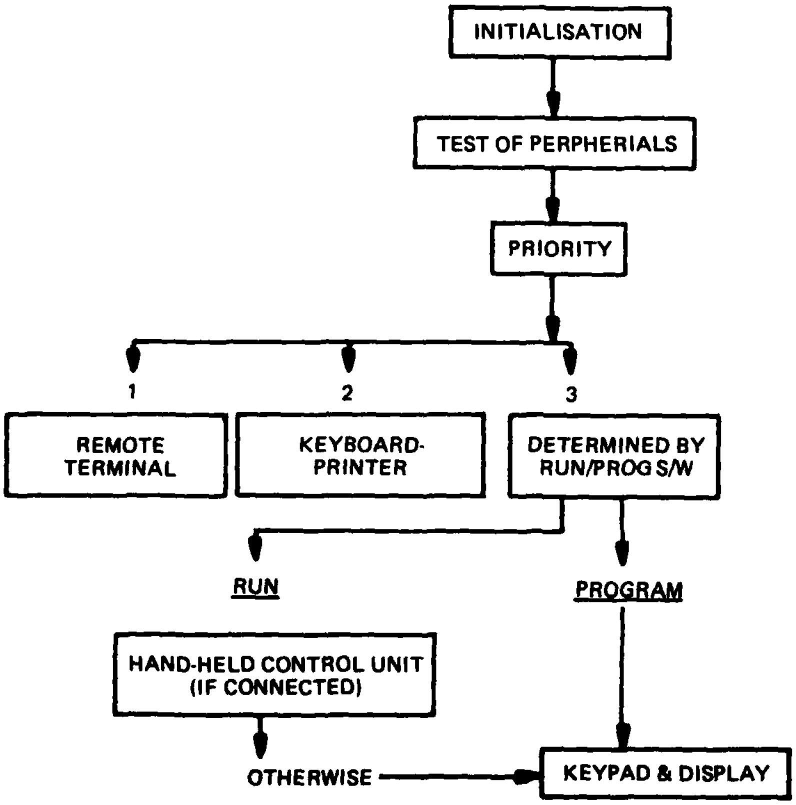


FIG. 13 PHERIPHERAL PRIORITY

Although the external displays are assigned specific parameters, the displays may be re-defined by a different application program. Sign control is achieved by the Most Significant Decade (*MSD*) strobe *b7* and the BCD word. A BCD word representing '7' or '1' produces a '+' sign or a '−' sign respectively. Decimal point and colon control details are shown in Fig. 11.

FIGURE 11

External Display Colon and Decimal Point Details

ALTITUDE DISPLAY	BCD WORD	STROBE	SELECT
D.P.1	0111	b4	b13
D.P.2	0100	b4	b13
NOT D.P.1 or D.P.2	0001	b4	b13
COLON 1	0111	b5	b13
COLON 2	0100	b5	b13
NOT COLONS	0001	b5	b13

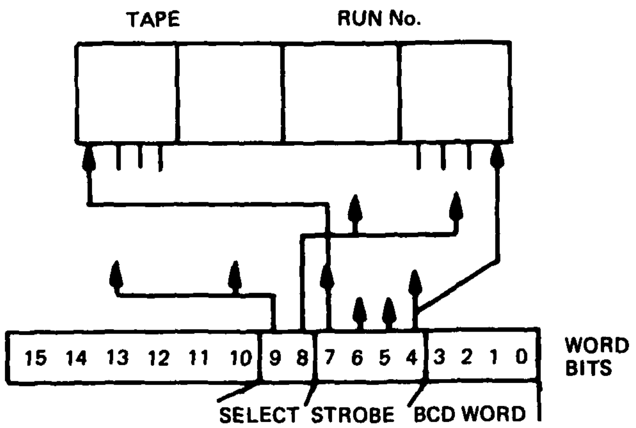
Binary values, as determined by the application program, need to be stored at specific memory addresses for display. These addresses are labelled DISS55 through to DISS99 and are assigned as in Fig. 12. The resident program accesses the addresses in sequence and converts each binary value to signed BCD prior to loading I/O PORT 1.

FIGURE 12

Assigned Addresses for External Displays

ADDRESS LABEL	ADDRESS HEX	SELECT	FUNCTION
DISS55	0E9	b8	PITCH
DISS66	0EA	b9	YAW
DISS77	0EB	b10	TEMPERATURE
DISS88	0EC	b11	AIRSPEED
DISS99	0ED	b12 &	ALTITUDE
CARRY	0EE	b13	

Identification of the external displays is automatically shown at INITIALIZATION by the resident program which assigns the codes (55 to 99) to the appropriate displays, provided that an application program is not selected.



NOTE HARDWARE CONNECTS TO RTC TO FLASH COLON TWICE A SECOND WHEN MADAR IS POWERED

FIG. 9 REMOTE CONTROL UNIT DISPLAY DETAILS

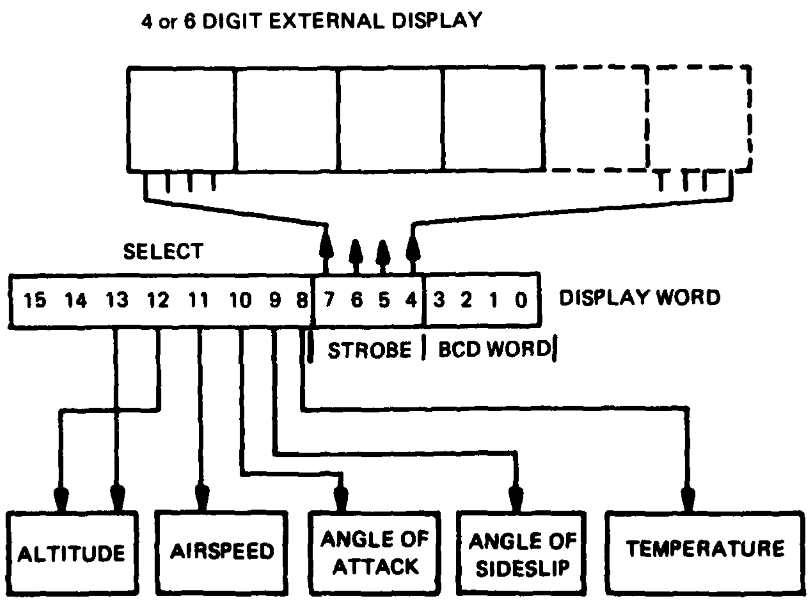


FIG. 10 SELECT – STROBE BIT ALLOCATION

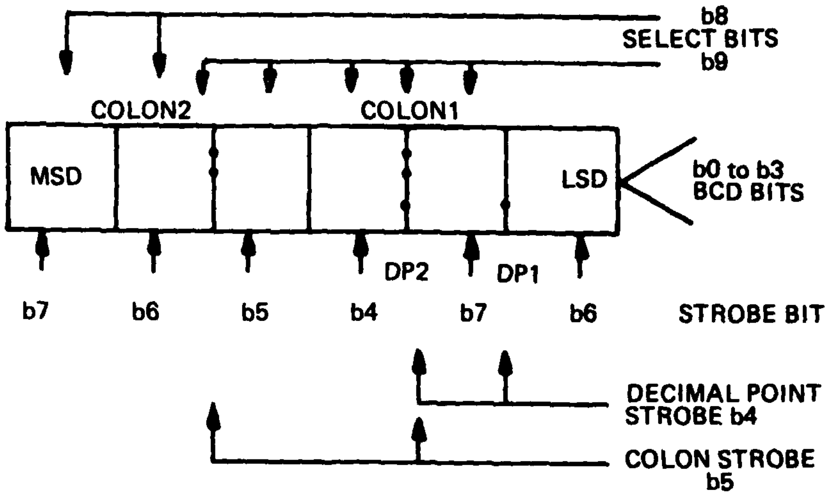


FIG. 8(a) DISPLAY-SELECT & STROBE BIT ALLOCATION

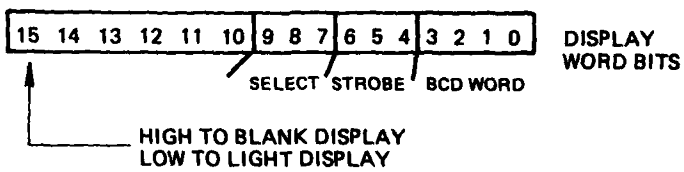


FIG. 8(b) DISPLAY WORD-BIT ALLOCATION

DISPLAY	BCD WORD	STROBE	SELECT
COLON1	0010	b5	b9
COLON2	0100	b5	b9
D.P.I.	0010	b4	b9
D.P.2	0100	b4	b9

FIG. 8(c) COLON & DECIMAL POINT DETAIL

DISPLAY CONTROL SEQUENCE

1. ADD STROBE & SELECT BITS TO BCD WORD
2. STORE DISPLAY WORD AT ADDRESS 0A000
3. WAIT 40 MICROSECONDS (MINIMUM)
4. MASK LOW THE SELECT BIT & RESTORE

FIG. 8 INTERNAL DISPLAY DETAILS

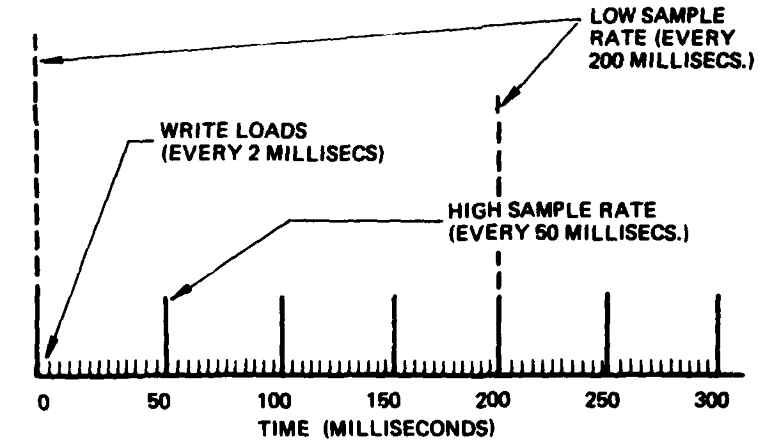


FIG. 6 TIME CALLS IN RECORD MODE

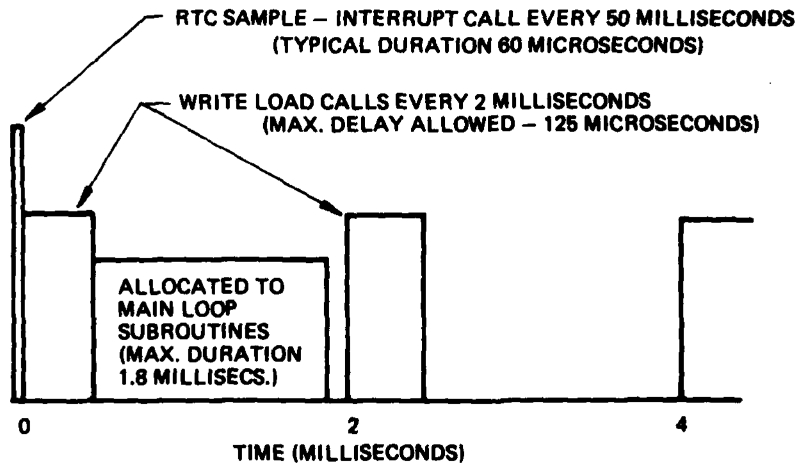


FIG. 7 CRITICAL TIME CONSTRAINTS IN RECORD MODE

4.4 RECORD Mode

The state of the RECORD switch is checked on every pass of the resident loop while in the RECORD mode. Only during the time that the switch is 'ON' is the level five interrupt enabled, so that the RTC is able to call the interrupt service routine every 50 milliseconds. When called, the routine clears the interrupt, sets a flag bit, re-enables the interrupt and exits the routine within 60 microseconds, to avoid possible erroneous control in time-sensitive sections of the RECORD mode resident loop.

The loop responds to the presence of the flag bit within a few milliseconds and calls a subroutine to address selected channels and store the gathered data, including the current 24-bit RTC word, in the buffer.

The rate at which the flag bit is set is constant and is hardware locked to the RTC. The delay, in reading data from selected channels, varies with loop commitments but is less than the 5 milliseconds resolution of the recorded RTC word.

To maintain a 4 : 1 sample rate ratio throughout the period that the REC switch is 'ON' the subroutine uses the CHAN word, initially and on every fourth call, to address all selected channels. For the three intermediate calls, the subroutine logically 'ANDS' the CHAN word with the FILTER word to address only those channels selected for HIGH sample rate.

Time calls which apply during a RECORD mode are shown in Fig. 6. Write calls are locked to the cassette recorder internal clock and are asynchronous with the sample rate derived from the RTC.

The time available to subroutines in the main loop is shown in Fig. 7.

4.5 Display Subroutines

4.5.1 Internal Display

The resident loop program services the internal display to provide a display of digits entered through the keypad or a display of selected data in response to a command.

The four lower order decades are controlled by a subroutine named SHOW while the two higher order decades are controlled by a subroutine named SHOW 2. Program details for the internal display are shown in Fig. 8.

4.5.2 Remote Unit Display

When the remote control unit is connected to *MADAR* the resident loop also services the four-digit display, within the unit, as two independent displays. Program details for the remote unit display are shown in Fig. 9.

The two right decades labelled 'RUN No.' increment once, whenever the operator presses and releases the push button RUN No. switch. The switch is sensed by an interrupt which decimal adds one to a counter then remains disabled for about half a second. This provides an adequate delay to minimize multiple increments but, with the switch held pressed, sets a controllable rate of about two increments a second.

The two left digits display the Tape Time Remaining and under software control decrement once for every six seconds (0·1 minutes) of tape motion.

4.5.3 External Displays

The external displays when connected to I/O PORT 1 are serviced about twice a second by the resident loop program.

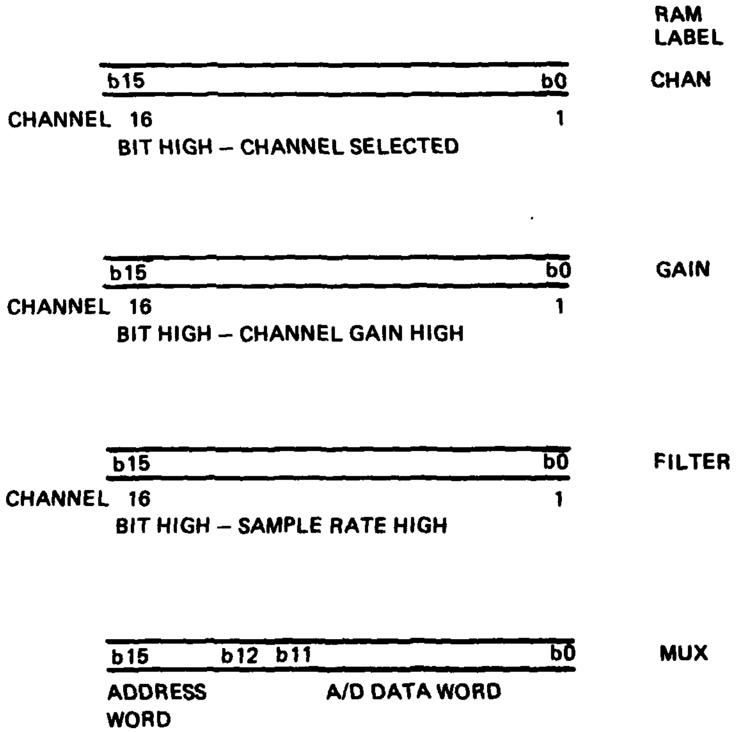
Strobe bits *b4* to *b7* of the display word (Fig. 10) steer the BCD word (*b0* to *b3*) to individual decades of the displays. The six-decade display uses bit *b12* to select the four right-decades and bit *b13* to select the two left-decades. The other displays are individually selected by bits *b8* to *b11*.

4.3 Selection Chages

In the PROGRAM mode the resident loop, accepts changes in channel selection, gain and sample rate. Three 16-bit *RAM* locations (CHAN, GAIN and FILTER) are coded (Fig. 5). A selection change, entered by the operator, alters the appropriate bit in one of the three locations.

GAIN and FILTER words are latched to the analogue low-pass filter cards prior to reading selected channel data. Low bits in the CHAN word cause corresponding channel addresses to the analogue multiplexer to be skipped during the RECORD mode. For the non-selected channels the corresponding bit states in GAIN and FILTER are arbitrary.

Care is needed in the interpretation of CHAN, GAIN and FILTER since bit 0 corresponds to channel 1 and bit 15 corresponds to channel 16.



CHAN. No.	ADDRESS
1	0000
16	1111

ANALOGUE (V)	CONVERTED DATA WORD
– 5	0000 0000 0000 0000
0	0111 1111 1111 1111
+ 5	1111 1111 1111 1111

FIG. 5 BIT ALLOCATION IN RAM ADDRESSES CHAN, GAIN, FILTER & MUX

TABLE 1

Keypad Commands—Alter

NN : 00 ALT	Changes Channel NN Select Status to Skip
NN : 11 ALT	Changes Channel NN Select Status to Low Sample Low Gain
NN : 22 ALT	Changes Channel NN Select Status to High Sample High Gain
NN : 12 ALT	Changes Channel NN Select Status to Low Sample High Gain
NN : 21 ALT	Changes Channel NN Select Status to High Sample Low Gain
30 : XX ALT	Changes Run No. to XX XX Range 00 to 99
40 : XX ALT	Changes Tape Time Remaining to XX XX Range 00 to 56
50 : ALT	Changes Status of all Channels to Skip
NN : 33 ALT	Selects Channel NN for Audio Alert
NN : 44 ALT	Deactivates Audio Alert at Channel NN
60 : XXX ALT	Sets Minimum Trip to XXX for Audio Alert XXX Range 000 to 999
70 : xxx ALT	Sets Maximum Trip to XXX for Audio Alert XXX Range 000 to 999 (Refer to Appendix for Audio Alert Values)

TABLE 2

Keypad Commands—Display

NN DIS	Display Channel NN Signal Voltage NN Range 01 to 16
20 DIS	Displays Real Time Clock in Seconds
30 DIS	Displays Run No. Range 00 to 99
40 DIS	Displays Tape Time Remaining in Minutes Range 5·4 to 0·0
50 DIS	Displays the coded Select Status of all Channels at 1 Channel/Second

TABLE 3

Displayed Error Codes

Display	Reason
99999 on Internal Display	Invalid Keypad Entry
02 Toggle to 00 all Displays	Attempting to Write on a Write Protected Tape

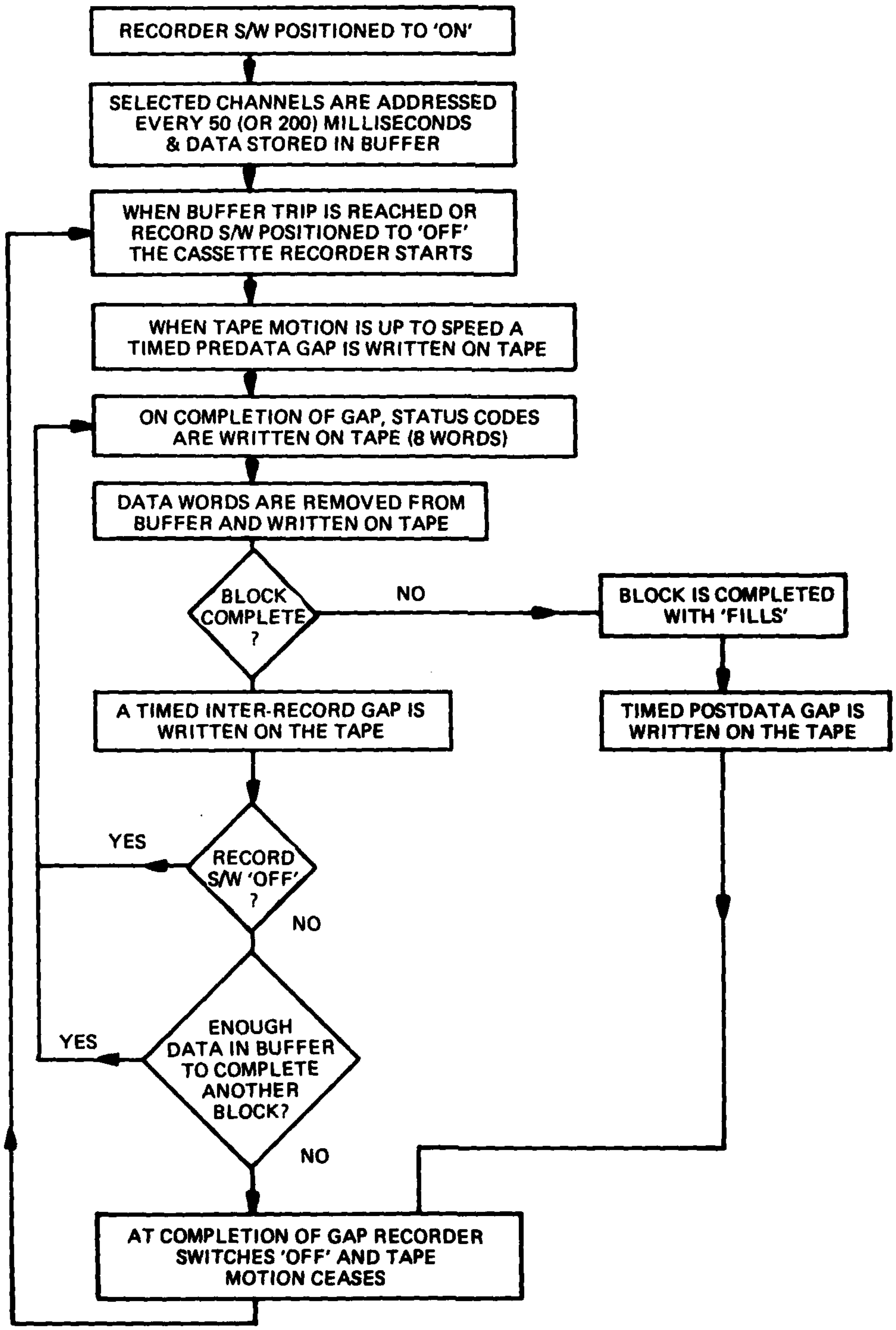


FIG. 4 RECORDER CONTROL DURING DATA GATHERING

5.2.9 Z—Plots Data from A Channel V Time

The 'Z' command enables a single selected channel to be plotted on an analogue $X-Y$ recorder against a selected time increment. Data, read from tape into the Data Buffer, are scanned and the selected channel data extracted, converted to an analogue signal (within the range ± 5 volts) and applied to the Y input of the recorder.

The X signal is incremented whenever a Y value is plotted and the X analogue step size is determined by the selected time increment.

As one block of data is plotted the next block is read from tape and the plot continues with the same channel number. When all data (may be many blocks) relating to the specified RUN No. are plotted, the tape automatically rewinds to the leading block of the entered RUN No.

The user is then prompted for another channel number. When plotting of channels within the blocks of the designated RUN No. is completed, the user exits the routine by pressing:

(a) the keyboard escape key

or

(b) the *MADAR* INITIALIZE switch.

The plotting routine is described by the flow chart in Fig. 15.

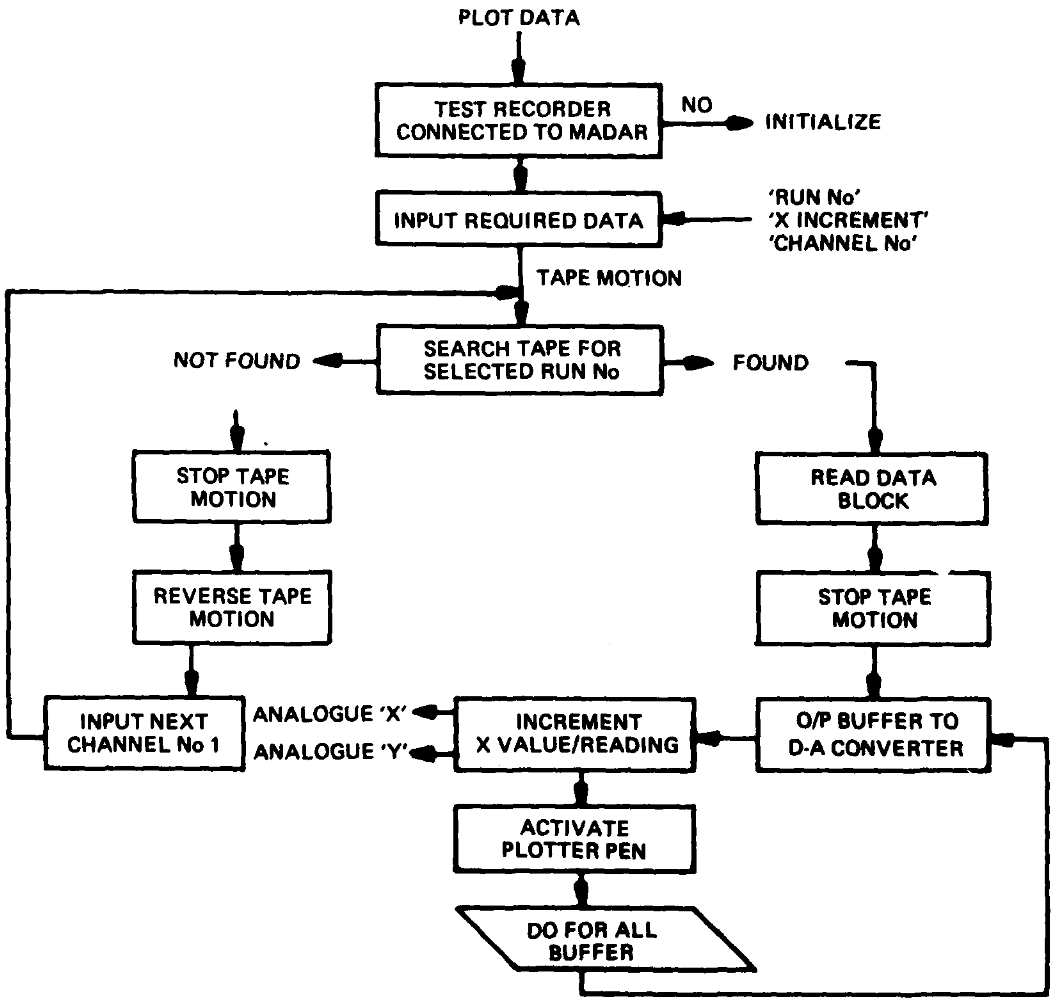


FIG. 15 'Z' PLOT ROUTINE

5.2.10 Q—Continuous Replay

The 'Q' command enables data to be read block by block from tape and transmitted via the RS 232 line to a remote terminal or computer. On completion of transmission the routine waits for a response from the user. Responding with any character, other than the terminator (carriage return), causes the routine to read and transmit the next block.

The user has the option to read data from a specific RUN No. or to read all recorded data. At the beginning of the routine the user is prompted by:

TYPE RUN No.

If a specific RUN No. is inserted, the routine searches to find the start of that block. (If (ABBA) is inserted all data blocks, regardless of RUN No., are read and transmitted starting with the first accessible block.

Continuous replay is appropriate for replaying data to the 9845 T Hewlett Packard desktop computer generally used to process data gathered by *MADAR*. The computer is programmed to accept, sort and display the received data block by block. A 'space' is automatically generated by the program to restart the cassette recorder and read the next block.

The continuous replay routine is described by the flow chart in Fig. 16.

5.2.11 X—Load Application Program from Tape

The 'X' command enables an application program, recorded on tape as an object file, to be read and loaded into *RAM*. The tape block lengths are identical to those used for data.

Each block starts with a common identification (RUN No.) followed by the block start address and the object file finish address. The remainder of the block contains the machine coded portion of the object file. The form is shown in Appendix 2.

The battery powered memory-save *RAM*, intended for application program use, extends from 0400 to 07FF (1K words).

The load routine is described by the flow chart of Fig. 17.

6. REAL TIME CLOCK

6.1 General

The RTC is derived from a hardware counter driven by a crystal oscillator. Digital output accessible to the CPU is a 24-bit true binary word which increments every 5 milliseconds (TABLE 4) and recycles in 83886 seconds (23·3 hours).

The lower order 12 bits is read from address RTCL (08800) and the upper order 12 bits is read from address RTCH (08400). Time lapse between software reading of RTCL and RTCH is about 40 microseconds when time is displayed on the internal liquid crystal display and about 25 microseconds when time is recorded on tape.

6.2 Time Synchronize

To enable the RTC to be synchronized to an event or with another *MADAR* system, the clock counter is able to be held RESET by:

(a) manually depressing the front panel 'TIMING SYNC' switch

or

(b) linking pins 1 and 5 on the front panel 'TIMING SYNC' connector.

Removal of the RESET allows counting to commence from a specific zero time reference.

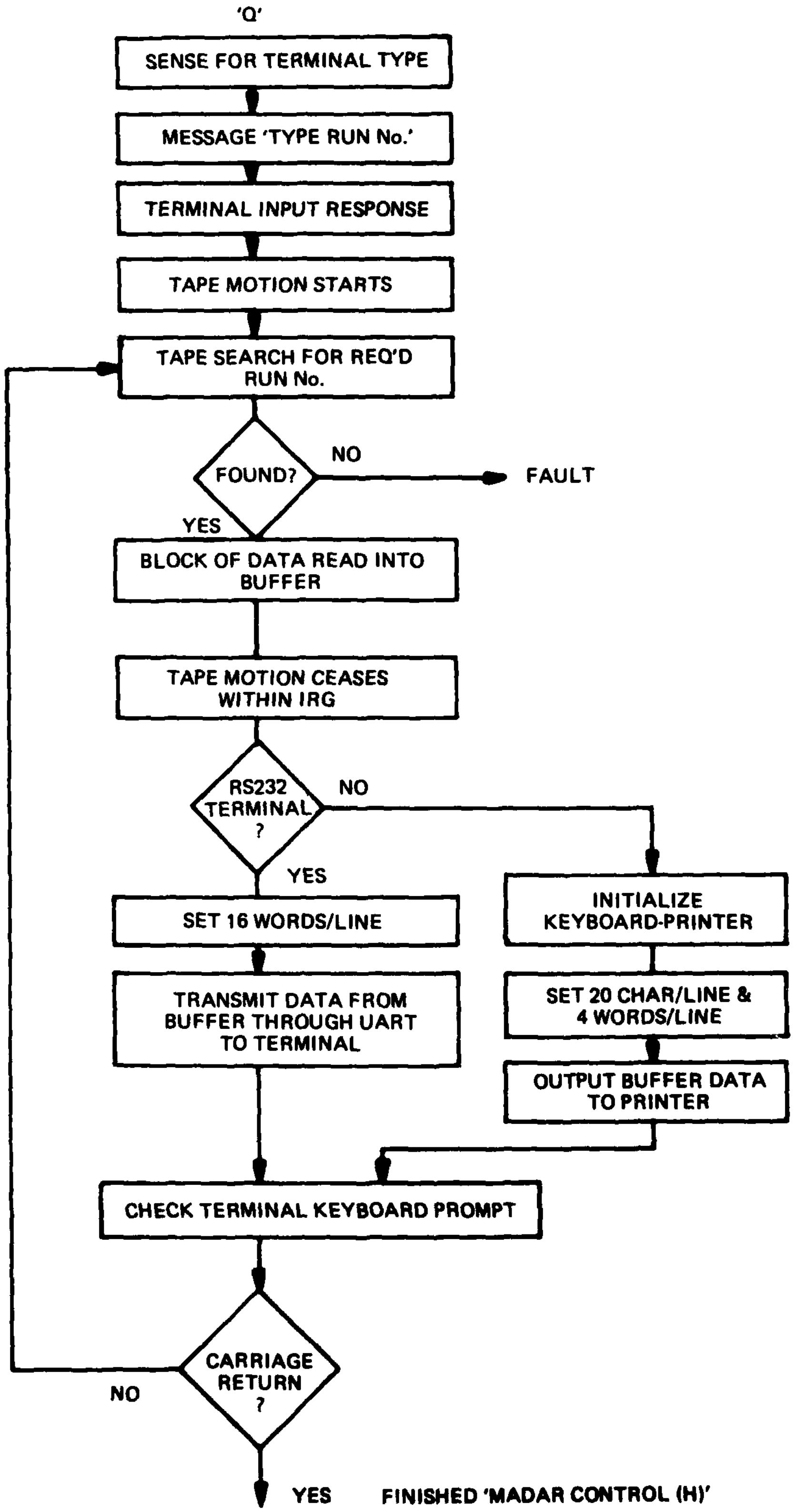


FIG. 16 'Q' COMMAND ROUTINE

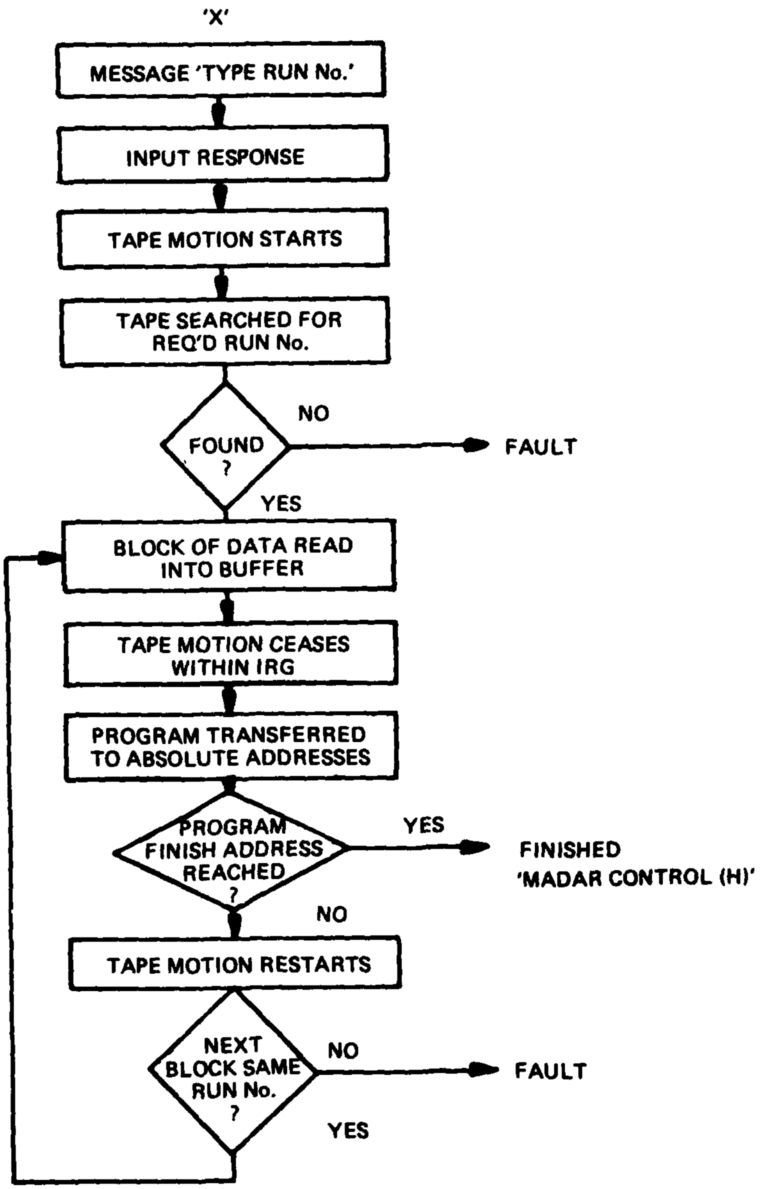


FIG. 17 'X' COMMAND ROUTINE

6.3 Time Display

For display purposes, the two 12-bit binary words read from the RTC are combined and code converted to 5 decimal digits with a resolution of 1 second.

The 5 millisecond resolution of the 24-bit binary time word is scaled by dividing by 200. This is achieved by a right shift (divide by 2) of the binary word and, following code conversion to decimal, by 8 right shifts (2 decade divide) of the decimal word.

The 23-bit binary word is software converted to the corresponding 7 decade decimal value in two stages. The 13 lower order bits convert to a 4 decade decimal value without exceeding the 16 bit word length of the microprocessor. The 10 higher order bits are converted using double double precision to avoid overflow. The algorithm places the 3 high decimal values in address CARRY and the 4 low decimal values in address BCD.

20

TABLE 4

Bit Weighting for Conversion of Binary Time to Decimal Time

Binary Bit	Time Value	Conversion Value	
0	5 milliseconds	Not converted	
1	10	1	
2	20	2	
3	40	4	
4	80	8	
5	160	16	
6	320	32	Single
7	640	64	Precision
8	1·28 seconds	128	
9	2·56	256	
10	5·12	512	
11	10·24	1024	
12	20·48	2048	
13	40·96	4096	
14	81·92	8192	
15	163·84	16384	
16	327·68	32768	
17	655·36	65536	
18	1310·72	131072	
19	2621·44	262144	Double
20	5242·88	524288	Precision
21	10485·76	1048576	
22	20971·52	2097152	
23	41943·04	4194304	

6.4 Time Delay Generation

Although non-critical time delays are required for gap generation control and Tape Time Remaining indicator, it is impractical to commit the microprocessor to software delay loops. This is because the main loop program also needs to control time dependent operations, the most critical being to complete a reload, within 125 microseconds, of the cassette interface every 2 milliseconds during data transfer to tape.

Time delays are therefore generated from the sensed binary state of the RTC during passes of the main loop program. Only the lower 12 order bits of the RTC are sensed, for time delay control, giving a binary time range of 0000 to 0FFF that represents nominally 20 seconds. The maximum delay needed is 6 seconds, for decrement control of the Tape Time Remaining indicator (Section 7.2). Delays of 0·2 seconds are required for pre-data, inter-data and post-data gap generation and a 0·5 seconds delay is used for updating displays.

An offset RTC value avoids time comparison uncertainty with the step change in binary time which occurs between 0FFF and 0000 (Fig. 18).

6.5 Offset

Figure 18 represents the 12 low-order bit range of the RTC. Assume that the main program reads the RTC at *t1*, for the purpose of initiating a delay of *td* seconds that is to expire at *t2*. The binary time *b2* at which the delay expires is determined by adding to *b1* a binary word *bd*, representing the delay required. The summed value is stored as the binary value *b2*. On subsequent passes of the main loop, the binary value of the RTC is read and compared with the value *b2*. When the binary value of the RTC is sensed as greater than the value of *b2* then the time delay has expired.

However, consider a time delay which starts at *t3* and is to expire at *t4*. If *t4* corresponds to a binary time of nearly 0FFF then there is a chance that the RTC could step to 0000 before the main loop samples a RTC binary word, with a value greater than that corresponding to *t4*. To avoid this problem, the binary time at the start of the time delay is added to the required *bd* word and the summed value compared with the offset trip level. If found to be greater, an offset time *t0* (Fig. 19) is also added prior to the binary value being stored. The value is stored and represents the time that the delay expires.

Included in *t0* is a flag bit (*b15*) the state of which is used by the main loop program to decide if subsequent RTC readings need to have an offset time of *t0* added before comparison with the stored value.

Consider, from Fig. 18, that the time zone of uncertainty is given by $(T-t1)$.

Provided that $(T-t1)$ exceeds the maximum cycle time of the main loop then a time check within the zone is assured. The time T for the RTC to increment from 0000 to 0FFF is *nominally 20 seconds*. Using a value for $t1 = 0{\cdot}9T$ conservatively sets the limit without offset at about 18 seconds, even though more than 100 redundancy checks could occur within the 2 second uncertainty zone assuming a 20 millisecond maximum cycle time of the main loop. The binary value corresponding to 18 seconds is 0E30. Also, as shown in Fig. 19, an offset time of $t0 = 0{\cdot}5T$ seconds is used. For $t0 = 10$ seconds the corresponding binary word is 0800 which becomes 08800 with flag bit included (Fig. 20).

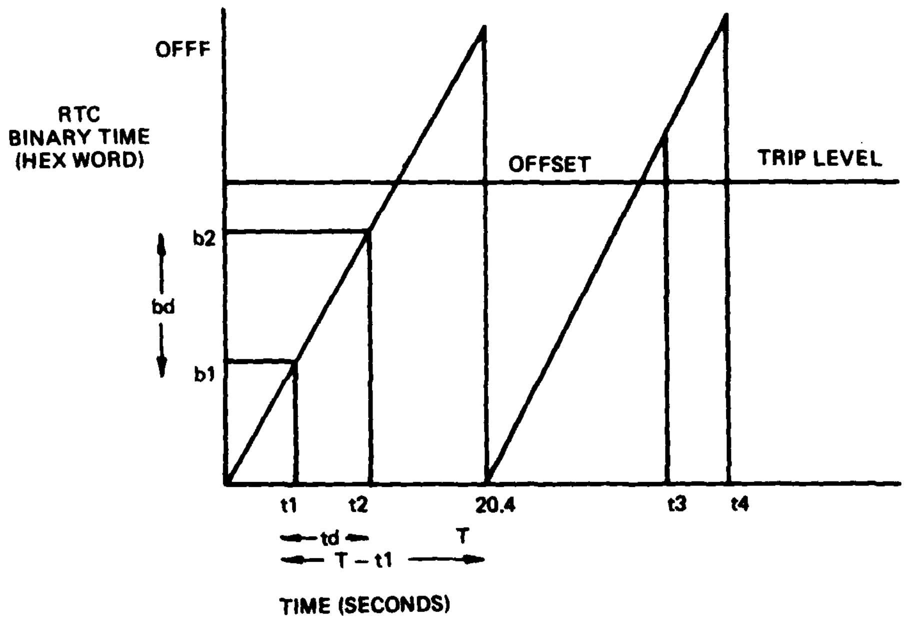


FIG. 18 REPETITIVE CYCLING OF LOW ORDER BITS OF RTC

6.6 Gap Generation

A nominal delay time *td* of 0·2 seconds is used for pre-data, inter-data and post-data gaps. The resolution of the RTC binary word and variations in the cycle time of the main loop cause the gap time to fluctuate.

The variation in gap lengths is proportional to the variation in gap time. At a tape speed of 254 millimeters/sec (10 inches/sec) the gap lengths may vary between 51 mm (2 inches) and about 58 mm (2·3 inches) which is within the specification range 17·8 mm (0·7 inches) to 250 mm (9·8 inches).[2]

6.7 Time Record

A significant and variable delay occurs between the start of a data scan (when selected analogue signals are sampled and stored in a buffer) and when the data (from the scan) are transferred from the buffer and recorded on tape. For meaningful RTC synchronisation between *MADAR* units (Section 6.2) to be maintained on replay requires that the recorded RTC values not be time shifted with respect to the recorded data.

A simple solution would be to include the RTC value in every data gathering scan as the seventeenth channel. Unfortunately, with 16 data channels each assigned for 12 data bits and 4 address bits data words there is no redundancy in the 4 bit identification address.

For replay convenience, the RTC has been allocated a two word position within the 8 word status code which appears at the beginning of every recorded data block. The double word contains the 24 bit RTC value applicable at the time that the leading data word of the recorded block was sampled; not the RTC value at the time that the data word was written on the tape.

A progressive count of the number of data words sampled by the A/D converter is maintained by the multiplexer section of the main loop program. A look-ahead check is made prior to every data gathering run to identify, in advance, the scan which will produce the data reading that later appears as the leading data word of a tape recorded data block. Whenever such a reading is identified the high and low words of the RTC are read and stored for later access.

A circulating buffer, of smaller capacity than that used for the storage of data, is used for the storage of the RTC values. Each RTC store and remove operation requires a double increment of the buffer 'IN' and 'OUT' pointers.

The recorded RTC provides a resolution of 5 milliseconds but synchronization accuracy depend primarily on the hardware/operator technique used to remove the reset from the RTC counters (Section 6.2).

7. TAPE USAGE

7.1 General

The minimum tape length in a digital cassette is specified[2] as 86 metres and at 254 millimetres/sec gives about 340 seconds (say 5·6 minutes) of continuous write time.

In practice, the available record exceeds 5·6 minutes because the tape does not run continuously even though data may be gathered with the RECORD switch held 'ON'.

7.2 Tape Time Remaining Indicator

A 2-digit liquid crystal display in the hand-held remote control unit displays (in minutes) the Tape Time Remaining.

Ref. 2. American National Standards Institute, Inc (ANSI X3.48-1977).

When tape motion initially starts, a binary word representing 6 seconds (0·1 minute) is added to the sensed RTC and the value stored in the main loop program symbolic address TAPTIM. Whilst tape motion continues, the incrementing value of the RTC is regularly checked against TAPTIM. When the RTC value becomes greater than the value TAPTIM the display is decremented by one and TAPTIM value incremented by a value corresponding to 6 seconds, to set the time for the next decrement to occur in the display of Tape Time Reaaining.

Whenever tape motion stops, the TAPTIM value is immediately overwritten by the value of the unelapsed portion of the 6-second period. When tape motion restarts this unelapsed value is added to the RTC and stored in TAPTIM to provide the next decrement time.

To reduce program time in packing and comparing 24 bits from the RTC with the TAPTIM value, only the low order 12 bits of the RTC are sensed. This involves generating an offset value similar to that as described in Section 6.5.

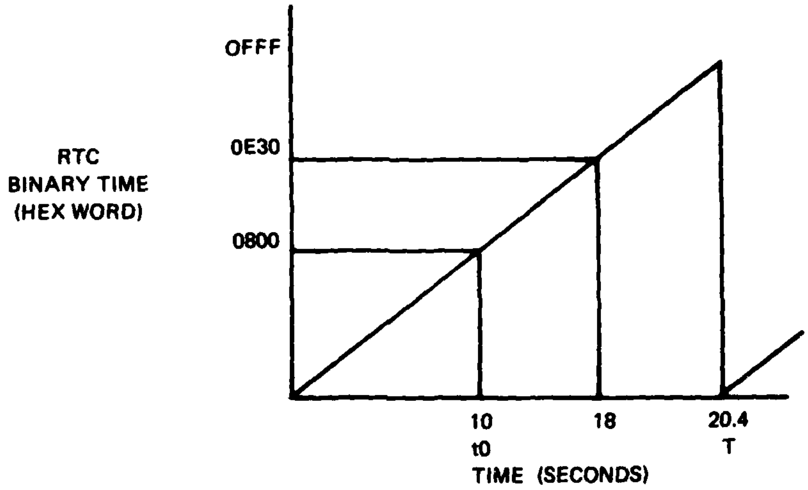


FIG. 19 OFFSET VALUE USED FOR TIME DELAYS

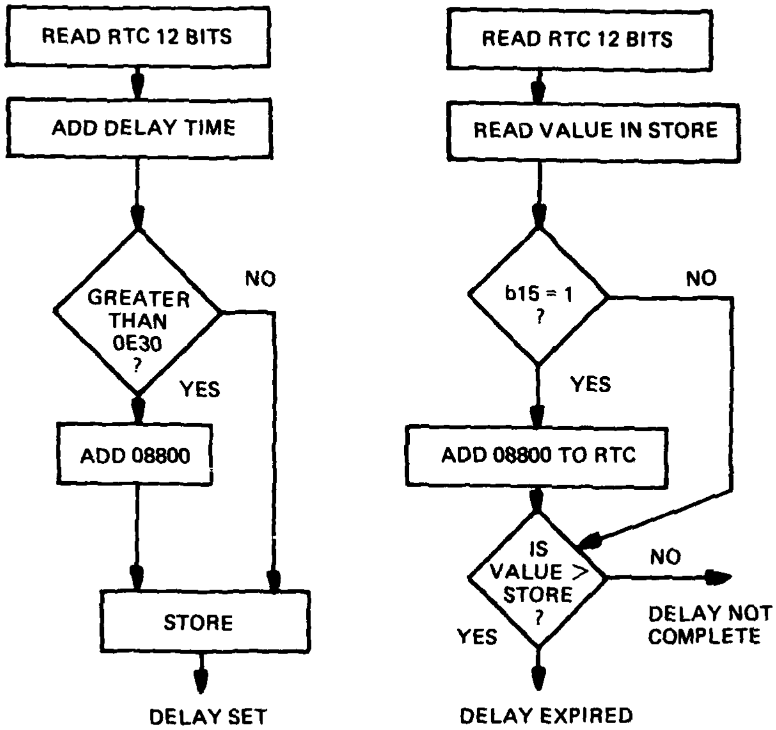


FIG. 20 SUBROUTINES FOR RTC CONTROLLED DELAYS

7.3 Tape Record Capacity

From Appendix 3 a digital cassette has the capacity to store a minimum of 370 data blocks. Each block contains 256 data words with 16 bits/word.

8. MODULE CONSTRUCTION

8.1 General

Physically, *MADAR* was dimensioned to fit a Sky Hawk ammunition tray compartment. However, combination of non-MIL components, unpressurized location and the need for through bulkhead cable connections to the cockpit for control and display suggests that installation in the RADOME or in a drop 'store' also be considered.

Standard aluminium extrusion was used extensively in the fabrication of the module (Fig. 21).

The front panel (Fig. 22) is fitted with labelled switches, indicator lights and connectors. To minimize incorrect usage, many of the switches are located beneath a quick release cover.

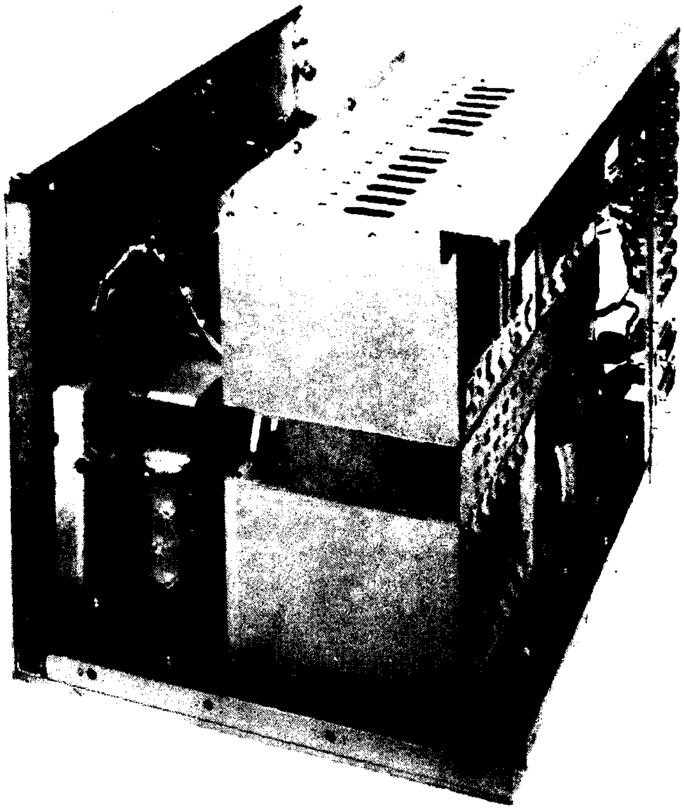


FIG. 21 MADAR SHOWING CONSTRUCTION DETAILS

8.2 Card Set

Printed circuit cards from an in-house designed set are used extensively throughout the module. Simplified interconnection is shown in Fig. 23 and address allocation of cards is detailed in Appendix 4.

Bit allocation for the cassette command and three-state interface card is covered in Appendices 5 and 6. The Central Processor Unit (CPU), memory (*ROM* and *RAM*), Universal Asynchronious Receive Transmit (*UART*), Input/Output (I/O) and Digital to Analogue (*D/A*) cards perform conventional functions. A memory map is given in Appendix 7.

A brief description follows for the memory save, battery charger, remote power ON/OFF and regulated power supply circuits.

8.2.1 Memory Save

Information stored in *RAM* is retained on power-up and power-down, by a 4-cell Nickle-Cadmium battery (4·8 volts) and a memory save circuit that monitors the power supply condition.

The memory save circuit monitors the level of the +10 volt unregulated supply from which the +5 volt regulated supply is derived. On power-down the supply decays to almost zero within 34 milliseconds and on power-up rises to within a few percent of final voltage within 5 milliseconds. During these periods the sensed +10 volt supply also falls and rises. A zener diode switching network is set to switch 'OFF' as the voltage decays below +7·5 volts and switch 'ON' when the voltage rises above +7·5 volts.

The value of 7·5 volts is important in that the regulating integrated circuit requires a minimum of +2·2 volts between input and output to regulate at +5 volts under full load current.

When powered-up, the memory save circuit switches ON and the forced initialization state is removed allowing the microprocessor to interrogate the bus. The forced 'not selected' mode is removed from the *RAM* cards in slots 3 and 4 (addresses 0000 and 0400). After a 1·9 second delay, the forced inhibition on cassette motion is removed. This prevents uncontrolled fast-forward motion of the tape which may occur under certain conditions.

8.2.2 Battery Charger

Whenever the module is powered, the internal battery charger compares the voltage of the nickel battery with a pre-determined reference value derived from the +15V regulated supply.

The voltage comparitor switches a constant current source to charge the cells automatically as required. The cells have a 2 ampere hour capacity and the charger current is set to 150 milliamperes.

While powered, the current drain on the internal battery is typically 45 milliamperes and increases to 60 milliamperes during the period that external power is switched OFF but with the *RAM* BATTERY switch ON.

8.2.3 Remote Control ON/OFF Power

With the remote control unit connected to the module, the power switch (protectively located at the top of the hand-held unit) switches battery power to an opto-isolator package. In the 'ON' position of the power switch, the emitting diode of the opto-isolator draws about 1·4 milliamperes from the battery supply and the light sensitive transistor portion forms a relaxation oscillator in conjunction with a bi-directional diode, capacitor and triac.

The primary winding of the power transformer connects to the mains supply through the triac. An oscillatory period of 10 microseconds ensures early conduction throughout each mains cycle, even at 400 Hz.

With the power switch 'OFF', no oscillation occurs as the opto-isolator limits the capacitor charge voltage to about 12 volts which is insufficient to trigger the bi-directional diode, so the triac remains non-conducting.

8.2.4 Regulated Power Supply

For general purpose aircraft application the choice of electrical power was between 26 VDC or 115V 400 Hz with the latter being chosen. To extend further the potential of *MADAR*, with the penalty of added bulk, the power transformer was designed for 115V, 50 Hz operation for convenience at ground sites (240V, 50 Hz mains) and aboard ships (115V, 60 Hz).

A survey of manuals for a selection of fixed and rotary wing aircraft showed that the Sky Hawk had the widest specified supply range of 115V$\pm$6V @ 400 Hz.

The regulated power supply module (Fig. 25) was tested at 50 Hz and 400 Hz with primary supply voltages of 108, 115 and 120. For the rated loads (TABLE 5) at 115 volts the primary current at 50 Hz was 1·6 amperes and at 400 Hz was 1·4 amperes. The regulated supplies remained within $\pm 1\%$ of nominal value and the heat sink temperature stabilized after 1 hour (in free air at an ambient temperature of 25°C) at 50 Celsius (400 Hz) and 56 Celsius (50 Hz).

TABLE 5

Rated Loads for Regulated Power Supply

+ 5V @ 5A +15V @ 1·5A −15V @ 0·5A	Common Return
24V @ 0·9A	Floating Supply

On power-down the memory save circuit switches OFF and the microprocessor is forced into a prolonged initialization state inhibiting further interrogation of the bus. Simultaneously, the *RAM* is forced into the 'not selected' mode and cassette motion inhibited. Details of the timing operation of the memory save circuit are shown in Figure 24.

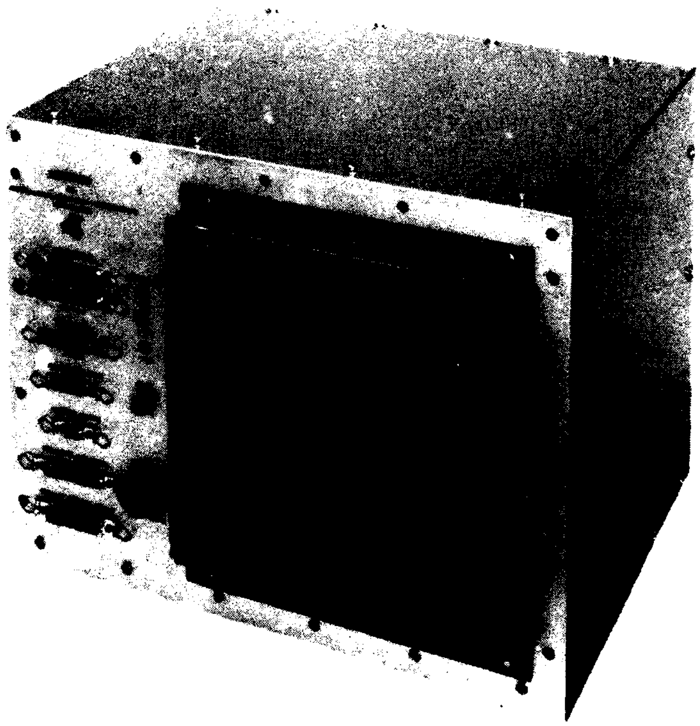


FIG. 22 MADAR WITH PROTECTIVE FRONT COVER

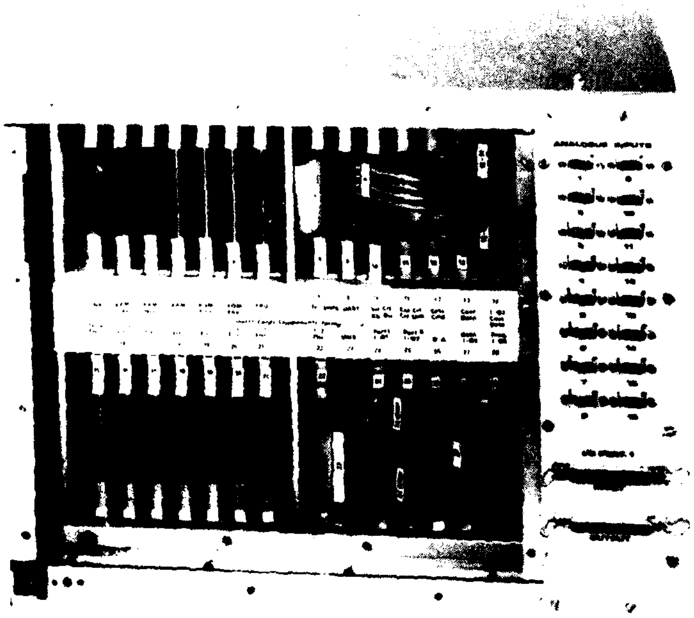


FIG. 23 REAR VIEW

9. TRIALS USAGE

Two *MADAR* modules complete with carrying cases fitted with documentation compartments were provided to AMAFTU.

For First of Class Flying Trials, one module is fitted to the aircraft and the other installed aboard the ship. Thus, on replay, the ships motion and that of the aircraft may be time collated and compared with other recorded parameters (Fig. 26).

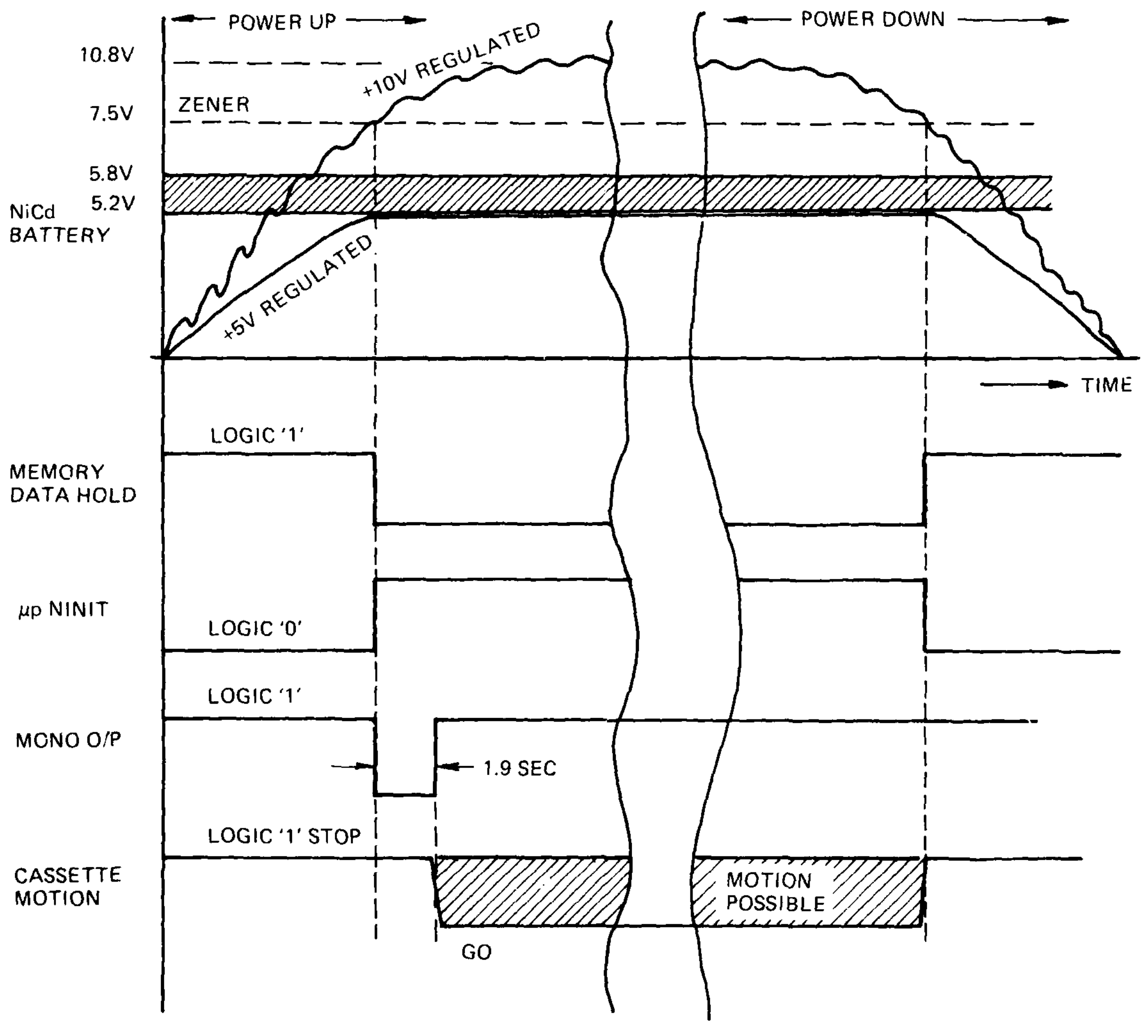


FIG. 24 MEMORY SAVE TIMING

APPENDIX 6

Bit Allocation for Three State Interface

BIT	SELECTION (By Bit Store into Address 08000)
0	RESET BIT FOR CHANNEL No. 11 FOR PEAK DETECTOR USE
1	LOW FOR SILENCE HIGH FOR BEEP
2	HIGH FOR EXT. CONTROL
3	
4	HIGH FOR UART SELECTION
5	LOW FOR H Z HIGH FOR A/D MUX (INT. LEVEL 4)
6	HIGH FOR RECORDER
7	HIGH FOR RTC 50 MILLISEC. CALL (INT. LEVEL 5)

BIT	SENSE (By Bit Load from Address 0800)
8	LOW IF S/W IN RUN HIGH IF S/W IN PROG.
9	LOW IF A DEVICE CONNECTED TO FRONT PANEL 'TERMINAL'
10	LOW IF A DEVICE CONNECTED TO I/O PORT 2
11	LOW IF HAND HELD REMOTE CONTROL UNIT CONNECTED
12	LOW WHEN A/D CONVERSION COMPLETE
13	
14	SPARE
15	LOW UNTIL END OF CHARACTER TRANSMISSION COMPLETED

APPENDIX 5

Bit Allocation for Cassette Command Interface

BIT	SELECTION (By Bit Store into Address 0B000)
0	LOW FOR FORWARD, HIGH FOR REVERSE
1	LOW TO START, HIGH TO STOP
2	LOW FOR FAST, HIGH FOR SLOW
3	LOW FOR TRACK 2, HIGH FOR TRACK 1
4	LOW FOR NO WRITE, HIGH FOR WRITE
5	LOW TO DISABLE READ, HIGH TO READ
6	LOW FOR GAPS, HIGH WRITES DATA

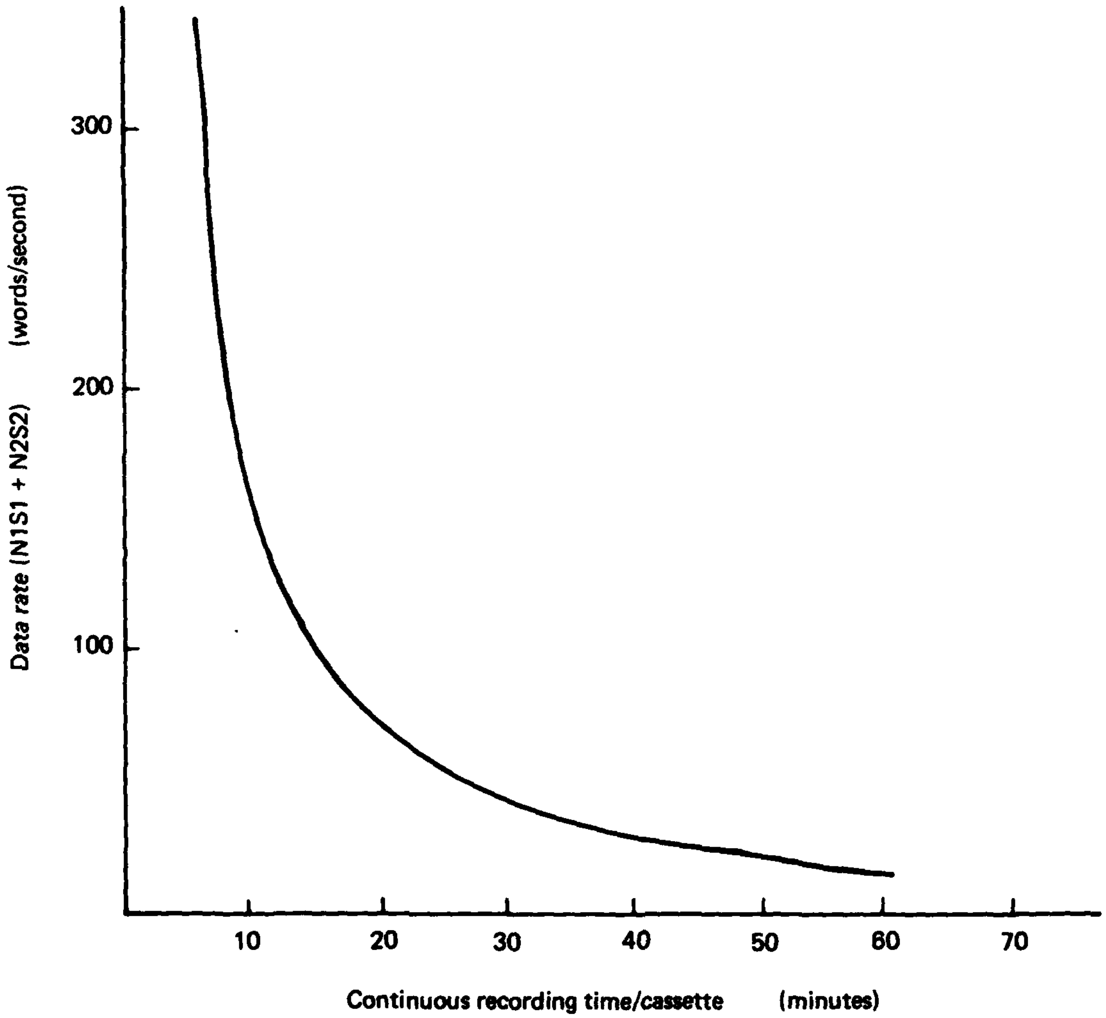
BIT	SENSE (By Bit Load from Address 0B000)
0	LOW IF IN FIRST HALF, HIGH IF IN SECOND HALF
1	LOW IF LEADER CLEAR, HIGH IF TAPE
2	LOW IF NO TAPE MOTION, HIGH IF TAPE IS MOVING
3	LOW IF CASSETTE PRESENT, HIGH IF NO CASSETTE
4	LOW IF WRITE UNPROTECTED, HIGH IF READ ONLY
5	LOW IF SIDE B, HIGH IF SIDE A
6	CLOCK SIGNAL
7	LOW TO WAIT, HIGH WHEN READY

APPENDIX 4

Addresses used by Memory and Interface Cards

ADDRESS (HEX)	ALLOCATION
0000–03FF	IK *RAM* (BATTERY POWERED FOR MEMORY SAVE)
0400–07FF	IK *RAM* (BATTERY POWERED FOR MEMORY SAVE)
0800–0B00 (or 017FF)	IK *RAM*
06000	EXTERNAL DISPLAYS (I/O1)
06800	D/A CONVERTER
07000	KEYBOARD/PRINTER (I/O2)
07400	UART
08000	TRI-STATE CONTROL
08400	RTC (HIGH ORDER)
08800	RTC (LOW ORDER)
09000	ANALOGUE MULTIPLEXER
09400	FILTER CUT-OFF AND SAMPLE RATE (I/O5)
09800	CHANNEL GAIN (I/04)
0A000	KEYPAD & INTERNAL DISPLAY
0A400	EXTERNAL CONTROL
0B000	CASSETTE COMMAND
0B800	CASSETTE COMMAND
0B800	CASSETTE DATA (I/03)
0F00–0F7FF	2K *ROM*
0F800–0FFFF	2K *ROM*

APPENDIX 3



CONTINUOUS RECORDING TIME/CASSETTE AS A FUNCTION OF THE NUMBER OF SELECTED CHANNELS AND ASSIGNED SAMPLE RATES

APPENDIX 3

Recorder Writing Rate

The writing rate of the cassette recorder is derived from the manufacturers specification.[4]

Bit density 31·5 bits/mm (800 bits/inch)

Tape writing speed 254 mm/sec (10 inches/sec)

This produces a writing rate of 8000 bits/sec which is equivalent to 1000 bytes/sec. Since *MADAR* data words are 16 bits (2 bytes) the writing rate is nominally 500 data words/sec.

The recorder write interface requires that a data word be loaded every 2 milliseconds while writing data on tape.

Storage Capacity/Cassette

Bit density is set by the recorder at 31·5 bits/mm (800 bits/inch). The tape length needed to store 264 data words of 16 bits each is 132 mm (5·2 inches).

Each pre-data, inter-data and post-data gap is nominally 0·2 second and occupies 51 mm (2 inches) of tape. The recorder, when trip started by the buffer during a continuous recording run, writes between 2 and about 10 data blocks on to tape without stopping. The actual number depends upon the data gathering rate given by ($N1 * S1 + N2 * S2$). During tape motion a minimum of 3 gaps and 2 data blocks through to a maximum of 11 gaps and 10 data blocks are recorded. This corresponds to a range of between 370 and 450 data blocks/cassette respectively.

Continuous Recording Time/Cassette

Typically, at minimum data gathering rate there are 370 data blocks stored on a digital cassette during continuous recording. At the maximum data gathering rate, about 450 blocks are accommodated on the tape.

The time required to gather the 256 words which contribute to a data block of 264 words is:

$$t = 256/(N1 * S1 + N2 * S2) \text{ Seconds}$$

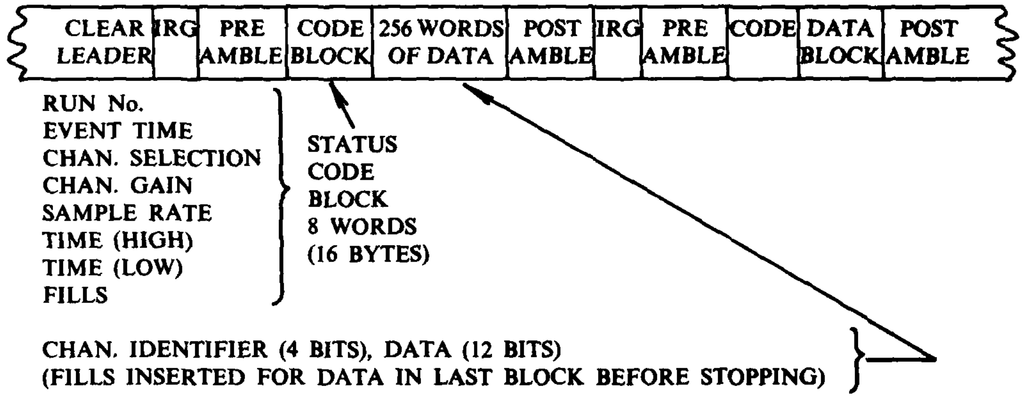
Thus, at the minimum gathering rate of 5 data words/second ($N1 = 0$, $N2 = 1$, $S2 = 5$) the time required to gather 370 data blocks is about $5\frac{1}{4}$ hours.

At the maximum gathering rate of 320 data words/second ($N1 = 16$, $S1 = 20$, $N2 = 0$) the time required to gather 450 data blocks is about 6 minutes.

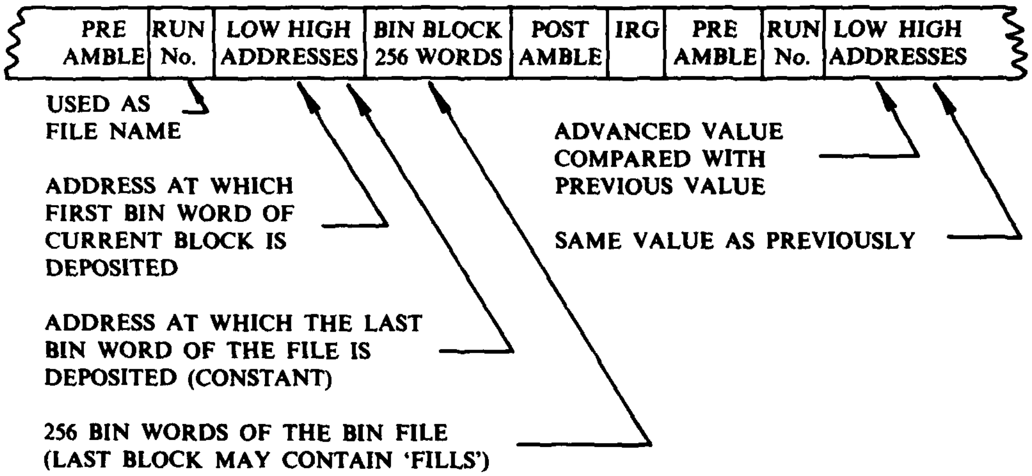
[4] Braemer Computer Devices Inc. Instruction and Interface Manual for Braemar Model CS-400 digital cassette tape transport system.

APPENDIX 2

Form of Recorded Data



Form of Recorded Bin (Object) File



Physical Size	:	475 mm × 345 (370) mm × 355 (375) mm nominal. (Bracketed figures refer to No. 2 unit)
Weight	:	33 kilograms (nominal)

Remote Control Unit

Internal Display	:	4 digit liquid crystal display
Tape Time Reamining	:	2 digit decrements in 0·1 minutes
RUN No.	:	2 digit 00 to 99
RUN Switch	:	Push button to advance RUN No.
MARK Switch	:	Push button to record Real Time Clock at instant of position
Record Switch	:	3 position centre off (biased OFF one-way toggle ON other way)
Power 'ON' Switch	:	Lift and toggle (opto isolated from 115V AC supply)

External Display SET

FIVE Liquid crystal displays intended for:

ALTITUDE	:	6 digit	DISPLAY RANGE AND FUNCTION DETERMINED BY APPLICATION PROGRAM
AIRSPEED	:	4 digit	
TEMPERATURE	:	sign and 4 digits	
SIDE SLIP ANGLE	:	sign and 4 digits	
PITCH ANGLE	:	sign and 4 digits	

(A maximum of 8 displays are possible)

Monitor Unit

Facilities	:	REMOTE POWER ON/OFF & TOGGLE S/W
	:	SWITCHED VOLTMETER TO MONITOR SUPPLIES
	:	APPLICATION PROGRAM SELECTION S/W

APPENDIX 1

MADAR Module Specification

No. of Channels	:	Programmable 1 to 16
Sample Rate	:	Programmable 5 or 20 Samples/selected chan/sec
Low-Pass Filters	:	0·8 Hz or 5 Hz (nominal) 3db cut-off. (Program interlocked with sample rate) 4th order Butterworth
Analogue Inputs	:	Differential
Input Impedance	:	100 Kohms (minimum)
Common Mode Rejection	:	60 db (typical)
Analogue Channel Gain	:	Programmable 1 or 0·5
Analogue Range	:	±5 volts (unity gain)
Analogue/Digital Conversion	:	12 bits
Least Significant Bit (*LSB*)	:	2·5 millivolts (nominal)
Digital Word Size	:	16 bits (4 channel address, 12 data)
Internal Time Word	:	24 bits (*LSB* 5 millisec)
Range Before Recycle	:	83886·08 seconds (23 h 18 m 6 sec)
Internal Display	:	6 digit liquid crystal display (decimal point blinks for negative voltage)
Internal Keypad	:	10 digit, sign, 1 delimiter and 4 commands)
Memory	:	2k battery powered *RAM*
	:	1k normal *RAM* (not standard fit)
	:	4k *ROM*
Front Panel Switches	:	INITIALIZE
	:	*RAM* BATTERY
	:	TIMING SYNC
	:	TAPE REWIND
	:	PROGRAM/RUN
	:	5 Ampere circuit breaker
Front Panel Indicators	:	+15V, +5V
	:	TAPE MOTION
	:	FILE PROTECT
	:	SIDE CORRECT
	:	CASSETTE LOADED
	:	CPU HALT
Internal Battery	:	2 ampere hour nickel cadium rechargeable battery (4 C size cells)
Internal Charger	:	Charges from +15 volt internal supply
		160 MA charge with auto switch-off
Power Requirements	:	115V, 50 to 400 Hz; 180VA max (plus 70VA @ 400 Hz for internal fan)
Connectors (Rear)	:	16 ANALOGUE INPUT CHANNELS (±12 volts reg max 300 MA pick-off)
	:	I/O PORT 1 (External Displays)
Connectors (Front)	:	I/O PORT 2 (external keyboard/printer)
	:	ANALOGUE OUTPUT
	:	TERMINAL (RS232)
	:	FRONT PANEL TEST
	:	REMOTE CONTROL
	:	TIMING SYNC
	:	INPUT POWER

ACKNOWLEDGEMENTS

The authors are grateful to Lieutenant Commander A. R. Baker, ex-OIC of AMAFTU for specifying the concepts of *MADAR* and to Engineering Facilities at Aeronautical Research Laboratories for the design and manufacture of hardware.

Much of the electronic assembly and circuit evaluation involved I. M. Kerton, P. Ferrarotto and G. M. Binns. The power supply modules were produced and tested by W. E. Boswell.

The authors very much appreciated the co-operation of Lieutenant Commander P. J. Parker, OIC AMAFTU and Commander K. Engelsman, the rotary wing test pilot for First of Class Flight Trials with HMAS *Tobruk* when *MADAR* was first used. Notable contributions were also made by Lieutenant M. Curry, fixed wing test pilot, and Lieutenant D. Peters.

Software interfacing of *MADAR* with a Hewlett Packard 9845 T desk top computer was successfully performed by Mrs D. Edvi-Illes who demonstrated exceptional devotion and ability to develop, within 2 weeks, a working 500 line enhanced Basic program.

CONCLUSION

The *MADAR* units have been successfully and extensively used since May 1981 and have provided a means of producing analytical data from trials which were previously subjectively assessed.

The experimental *MADAR*'s were not constructed to MIL specifications. Never the less the units have been exposed to very harsh environments resulting, at times, in loss of data.

Urgent action is needed to procure a second generation system before the useful end-of-life of the existing units is reached.

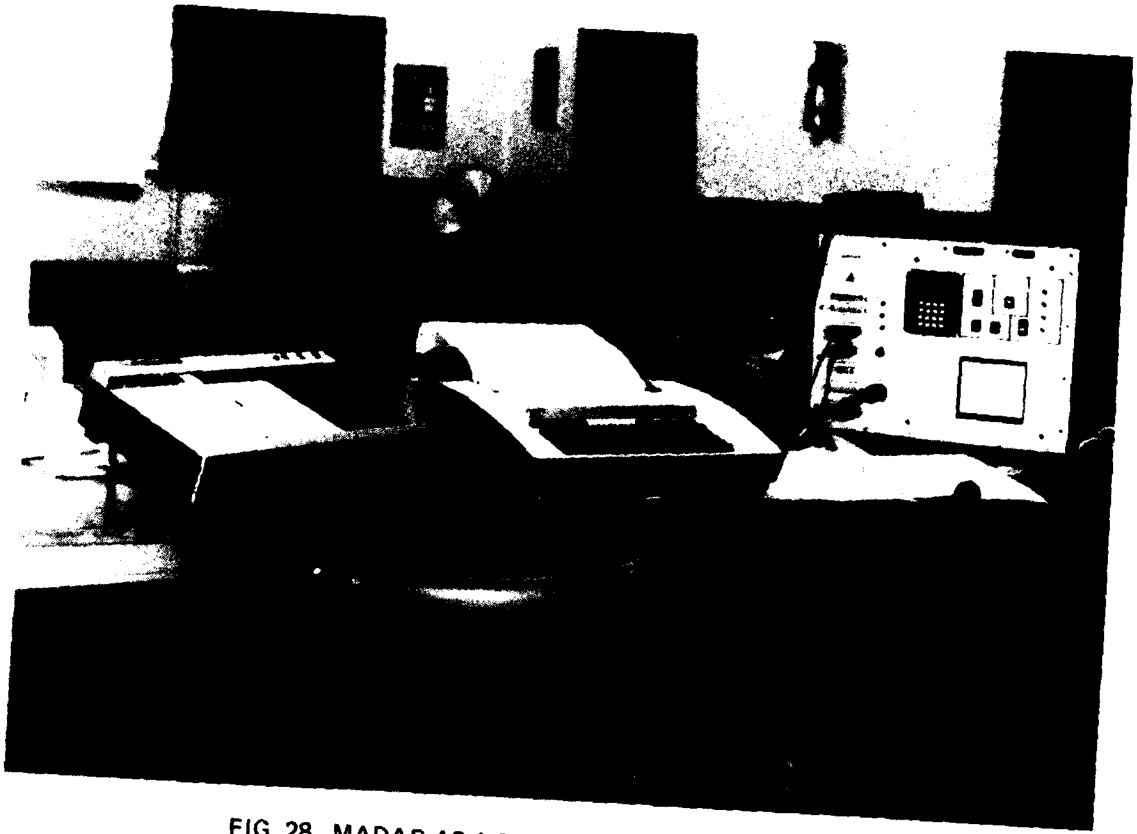


FIG. 28 MADAR AS A REPLAY & QUICK LOOK STATION

FIG. 29 BELL 206 HELICOPTER WITH MADAR IN REAR SEAT

(e) 1983-84 Torpedo Recovery Trials:

Data was recorded for stress analysis of a torpedo recovery cage while slung from a Sea King helicopter and operated in various sea state conditions.

FIG. 27 FIRST OF CLASS FLIGHT TRIALS, HMAS TOBRUK

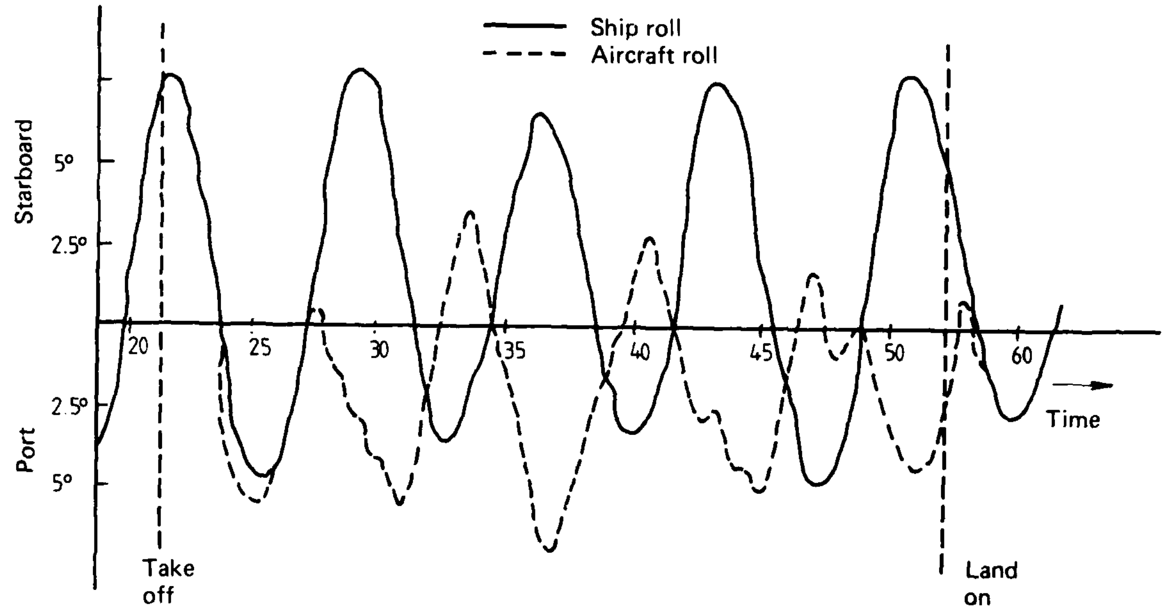


FIG. 26 COMPARISON BETWEEN AIRCRAFT ROLL AND SHIPS ROLL. FIRST OF CLASS FLIGHT TRIALS – WESSEX HELICOPTER TAKING OFF AND LANDING ON HMAS TOBRUK

MADAR has been employed on the following trials:

(a) May 1981 First of Class Flight Trials:
Wessex helicopter on HMAS *Tobruk*. Trials were conducted in Jervis Bay using both the central and rear decks of HMAS *Tobruk* (Fig. 27). Both navy *MADAR*'s were utilized for data recording, one for aircraft motion and the other ships motion. The third (ARL) *MADAR* was employed as a replay and quick look station back at AMAFTU (Fig. 28).

(b) March 1982 First of Class Flight Trials:
Bell 206 helicopter on HMAS *Adelaide*. Trials were conducted in a similar manner to that of the above trial. Figure 29 shows a *MADAR* mounted in the rear seat of the Bell 206.

(c) September 1982 First of Class Flight Trials:
Bell 206 helicopter on HMAS *Stalwart*.

(d) March 1983 Rushton Towed Target Trials with Sky Hawk Aircraft.
MADAR was installed into the ammunition bay of a Sky Hawk Aircraft to record raw flight data and to calculate and display, in real time, indicated airspeed, angle of side slip and angle of pitch.[3]

[3] Sutton, C. W., Harvey, J. F., and Kerton, I. M. Boom Application Program for MADAR and Cable Tension Monitor (Towed Target Trials), Aero Note 416.

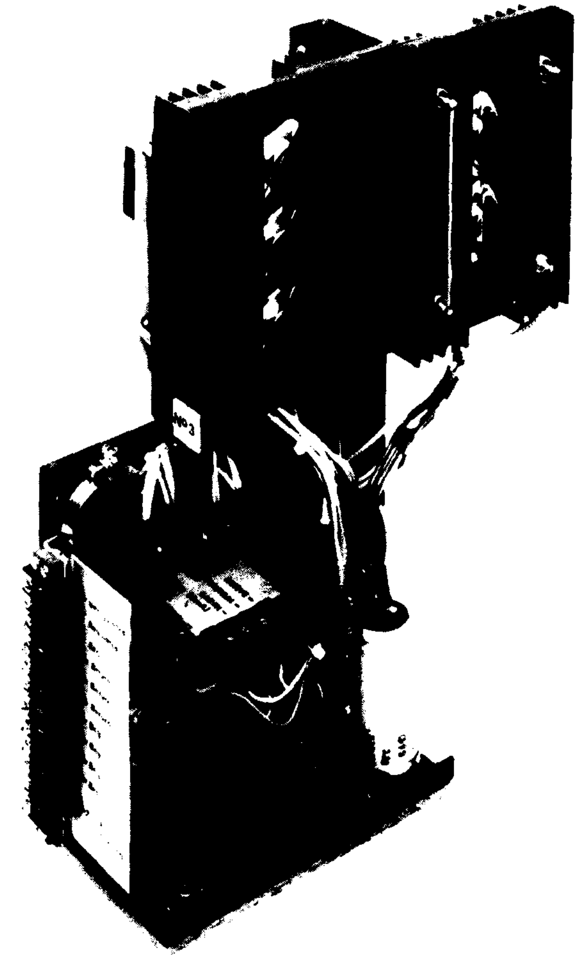


FIG. 25 POWER SUPPLY MODULE

APPENDIX 7

Memory Map

0000	
	(INTERRUPT & REPLAY)
06F	
070	
	(WRITE)
0D4	
0D5	
	(APPLICATIONS)
OFF	
0100	
	BUFFER USE
03FF	
0400	
	DEDICATED TO APPLICATION PROG RAM (1K)
07FF	
0800	
	APPLICATION PROG RAM/ROM (1K)
0BFF	
	INTERFACE CARDS ADDRESSES RANGE 06000 TO 0B800 (SEE APPENDIX 4)
0F000	
	RESIDENT WRITE PROG EPROM (2K)
0F7FF	
08800	
	RESIDENT REPLAY PROG EPROM (2K)
0FFFF	

APPENDIX 8

Pin Connections for Analogue Channel Connectors

PIN	FUNCTION	
	CHANS 1-13 (RAN) CHANS 1-16 (ARL)	CHANS 14-16 (RAN)
1	ANALOGUE INPUT (inverting)*	S1
2	ANALOGUE GROUND	S2
3	ANALOGUE INPUT (non-inverting)	S3
4	ANALOGUE GROUND	GROUND
5	+12V	+12V
6	COMMON	COMMON
7	−12V	−12V
8		R lo
9		R li

* Automatically becomes analogue ground when single-ended filter cards are used.

The ± 12 Volts regulated supplies are derived from a common source within the module. Total load current is 300 milliamperes, line regulation 0·1%, load regulation 0·05%.

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AR-003-009	ARL-AERO-R-159	March 1984	80/186

4. Title	5. Security	6. No. Pages / 7. No. Refs
MICROPROCESSOR AIRBORNE DATA ACQUISITION AND REPLAY (*MADAR*) SYSTEM	a. document: Unclassified; b. title: U; c. abstract: U	6. No. Pages: 44; 7. No. Refs: 4

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16. Abstract

This paper describes a self-contained data acquisition system capable of real-time data processing and display during recording.

Replay options include hard copy of data to an X–Y recorder or terminal printer and transfer of data to a computer.

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16. Abstract (*Contd*)		
17. Imprint Aeronautical Research Laboratories, Melbourne		
18. Document Series and Number Aerodynamics Report 159	**19. Cost Code** 57/2065	**20. Type of Report and Period Covered** —
21. Computer Programs Used —		
22. Establishment File Ref(s) —		

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